MAR 15 1929

W. B. No. 970

UNITED STATES DEPARTMENT OF AGRICULTURE
WEATHER BUREAU

VOLUME 57 NUMBER 1

MONTHLY WEATHER REVIEW

JANUARY, 1929

CONTENTS

	Page
Hourly frequency and intensity of rainfall at New Orleans, La. (4 figs.) J. P.	1
Meteorological survey of proposed [illegible] the San Francisco municipal airport. [illegible]	8
Father Gherzi, S. J., on the [illegible] rainfall of China. (2 figs.) A. J. Henry	12
Rapid decrease in barometric pressure [illegible] northwest of storm track on November 17, 1928. S. Belden. With note by R. H. Weightman	17
A dense smoke cloud on January [illegible] at Washington, D. C. (1 fig.) I. R. Tannehill	18
Correlation studies: Temperature [illegible] United States. F. Greissmayr	20
Heavy snowfall of January [illegible] Dubuque, Iowa. H. M. Wills	21
NOTES, ABSTRACTS, AND REVIEWS:	
An exceptional January [illegible]	22
Cold weather in [illegible] January, 1929. *Reply*	22
Atmospherics and tropical cyclones. Father E. Gherzi, S. J.	23
New edition of "Physics of the Air." A. J. H.	24
The Norwegian weather service. C. F. B.	24
The typhoons of 1927. A. J. H.	24
Tornadoes and line-squalls on January 18, 1929	24
Wettest November in southern Panama. C. F. B.	24
Meteorological summary for Chile for December and also the year 1928. J. B. Navarrete. *Transl. by W. W. Reed*	25
BIBLIOGRAPHY	25
SOLAR OBSERVATIONS	26
AEROLOGICAL OBSERVATIONS	28
WEATHER IN THE UNITED STATES	29
WEATHER OF THE ATLANTIC AND PACIFIC OCEANS	33
CLIMATOLOGICAL TABLES	36
CHARTS I–XIII.	

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1929

MONTHLY WEATHER REVIEW

Editor, ALFRED J. HENRY

VOL. 57, NO. 1
W. B. NO. 976

JANUARY, 1929

CLOSED MARCH 2, 1929
ISSUED MARCH 30, 1929

HOURLY FREQUENCY AND INTENSITY OF RAINFALL AT NEW ORLEANS, LA.

By W. F. McDONALD

[Weather Bureau Office, New Orleans, La., December 18, 1928]

Studies of rainfall frequency and intensity have been made at various places, based upon the precipitation automatically recorded at regular Weather Bureau stations.[1] Good records of hourly precipitation are, at most places, confined to the years since the late nineties, but it seems that there is not in print any study of hourly rainfall extending over as many as 30 years of record. Fairly complete hourly data for the New Orleans station for 30 years, 1898 to and including 1927, have been obtained by transcribing the amounts prior to 1905, shown by the original sheets now on file at this station.

The means of registration has been the self-recording rain gauge of the tipping bucket type, which gives the time distribution of rainfall measured in hundredths of an inch. The time intervals used for tabulations are the clock hours, with the recorded amounts conforming to the fixed hour lines marking standard time on the record sheets. None but the heaviest rainfalls are treated in Weather Bureau records, with reference to the time of occurrence of given intensities rather than upon the fixed clock hours.

This study treats the record in two aspects—frequency and intensity. Every hour with a precipitation record has been counted, to produce hourly, monthly, and annual totals for the 30 years.

In considering these hourly precipitation records as matter for statistical comparison it is well to consider several limitations. The first is that the hourly entries in the records prepared, as they must be, with reference to the 24 clock hours, are really random samples of precipitation intensity. Precipitation is irregular in time, particularly in the area which is represented by the New Orleans records. Any brief shower will produce an hour record, whether the duration of rainfall be for a few minutes or for a full hour or more. Precipitation extending a little longer than 60 minutes can and often does produce a record in three separate clock hours, as it may begin near the close of the first hour, extend through the next, and end shortly after the opening of the third hour. The summation of the hour entries for a period of years therefore runs to a total considerably greater than the true duration of rainfall, this being especially true for the region of the Gulf coast, where rainfalls are commonly of short duration.

While from a purely practical point of view, concerned with interference with outdoor work, transportation, sales, etc., the hours with *measurable rain* are admittedly the principal end of study, there is great interest, from the meteorological point of view, in including also the hours with any rainfall whatever; that is, hours in which only traces of rain are recorded. The fact that precipitation even in insignificant amount is occurring, is important as showing the existence of that combination of circumstances which may be briefly designated as the "rain condition." In summer especially traces often actually represent the occurrence of measurable and at times of heavy showers in the near vicinity, but showers of such limited compass that only the outer edge of the rainfall area affects the recording station.

Table 1 gives for the 30 years 1898–1927 the hourly and monthly sums of (*a*) hours with only a trace of precipitation, (*b*) hours with 0.01 or more inch of rainfall recorded within the hour, and (*c*) the sum of (*a*) and (*b*). The last figure may be properly considered the truer measure of frequency of the "rain condition."

It is true that because of the fact that traces of rain are not automatically recorded, these records are more subject to personal errors of observation. Light rainfalls in middle night hours are certainly not fully recorded, as the following consideration of the data will confirm: The grand total of all hours with traces of rain is only slightly diminished by those failures of record due to the lack of observations during night hours. Roughly, the monthly total of hours with traces of rain is 65 to 75 per cent of the total with measurable rainfall. Many of the hours between midnight and 4 a. m. have a much smaller proportion of recorded traces, running as low as one-third in some instances, and below the average proportion much more frequently than during the other hours of the day. This appears to indicate the loss of some records of traces of rain during those middle night hours. Moreover, the hours around 7 a. m., noon, and 7 p. m. appear to carry a somewhat larger than average proportion of traces to measurable rains; this leads to the suspicion that those times of day have been more accurately observed by reason of their being times when the observers are likely to be out of doors and therefore able to secure personal observation of very slight amounts of rainfall which might otherwise have escaped notice.

[1] Excellent studies of rainfall frequency and intensity have been published by Tannehill for the Texas coast, as follows:
Tannehill, I. R.: Wind Velocity and Rain Frequency on the South Texas Coast; Mo. Weather Rev., September, 1921, 49:496-499.
Tannehill, I. R.: Frequency Distributions of Daily and Hourly Amounts of Rainfall at Galveston, Tex.; Mo. Weather Rev., January, 1923, 51:11-14.
Hourly frequency studies for Chicago (1902-1911), are a part of the discussion of the climate of Chicago, in the following:
Cox, H. J., & Armington, J. H: The Weather and Climate of Chicago; pp. 205-208. University of Chicago Press. 1914.
Fassig, O. L. Report on the Climate and Weather of Baltimore and Vicinity. Baltimore. 1907. (Maryland Weather Service, v. 2, pp. 167-170.)
See also a brief discussion relating to foreign stations in J. Hann's Lehrbuch der Meteorologie, 4th ed., Leipzig, 1926, pp. 353-4.

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TABLE 1.—*Total number hours with rain at New Orleans, La. (1898–1927, inclusive)*

Month	Class of data counted	Hours ending— A.M. 1	2	3	4	5	6	7	8	9	10	11	Noon 12	P.M. 1	2	3	4	5	6	7	8	9	10	11	Mid. 12	Total
January	Traces A	39	42	36	44	37	39	56	63	50	47	32	45	63	53	53	47	38	50	42	60	55	39	42	44	1,116
	0.01 or more B	50	48	55	59	63	60	57	49	45	42	54	49	64	59	64	64	67	60	65	50	52	51	42	44	1,322
	Sum, a+b C	89	90	91	103	100	108	113	112	95	89	86	94	127	112	117	111	105	110	107	110	107	90	84	88	2,438
February	Traces A	28	24	22	35	40	38	42	53	44	36	33	44	56	41	41	37	40	38	40	51	47	41	30	38	939
	0.01 or more B	53	52	51	49	52	55	49	50	51	51	49	49	49	51	43	46	52	62	58	52	49	50	51	39	1,213
	Sum, a+b C	81	76	73	84	92	93	91	103	95	87	82	93	105	92	84	83	92	100	98	103	96	91	81	77	2,152
March	Traces A	21	20	23	23	29	37	34	50	36	34	37	38	49	50	45	42	53	43	38	37	39	35	32	18	863
	0.01 or more B	39	43	41	44	41	49	54	46	46	41	46	50	58	52	59	56	57	53	53	54	40	36	34	36	1,128
	Sum, a+b C	60	63	64	67	70	86	88	96	82	75	83	88	107	102	104	98	110	96	91	91	79	71	66	54	1,991
April	Traces A	7	8	12	12	15	24	32	44	32	22	23	29	31	29	29	24	33	27	32	29	21	13	16	12	556
	0.01 or more B	36	40	29	32	30	27	31	36	35	34	34	36	35	43	45	46	37	38	36	35	34	36	35	30	850
	Sum, a+b C	43	48	41	44	45	51	63	80	67	56	57	65	66	72	74	70	70	65	68	64	55	49	51	42	1,406
May	Traces A	8	7	12	14	17	18	26	30	18	14	28	30	38	37	36	23	30	33	27	25	21	19	17	11	539
	0.01 or more B	26	28	29	31	34	32	36	26	33	44	40	51	48	53	52	40	36	39	44	34	29	30	24	22	861
	Sum, a+b C	34	35	41	45	51	50	62	56	51	58	68	81	86	90	88	63	66	72	71	59	50	49	41	33	1,400
June	Traces A	13	10	12	12	17	16	14	22	34	36	38	57	68	70	49	53	43	37	37	30	23	16	18	13	738
	0.01 or more B	15	16	13	18	25	23	24	20	29	50	62	88	101	94	98	93	78	59	33	31	27	17	19	13	1,046
	Sum, a+b C	28	26	25	30	42	39	38	42	63	86	100	145	169	164	147	146	121	96	70	61	50	33	37	26	1,784
July	Traces A	8	6	9	13	12	23	35	34	28	48	47	75	97	70	73	64	52	60	55	33	25	22	17	11	917
	0.01 or more B	10	8	15	26	29	31	34	32	48	54	82	104	124	126	114	108	77	70	45	35	26	23	18	13	1,252
	Sum, a+b C	18	14	24	39	41	54	69	66	76	102	129	179	221	196	187	172	129	130	100	68	51	45	35	24	2,169
August	Traces A	7	7	12	15	15	10	24	26	21	24	42	64	87	76	69	65	55	45	55	35	27	12	16	8	817
	0.01 or more B	13	13	15	22	22	17	18	17	31	44	69	94	111	128	105	92	86	72	48	28	23	22	13	15	1,118
	Sum, a+b C	20	20	27	37	37	27	42	43	52	68	111	158	198	204	174	157	141	117	103	63	50	34	29	23	1,935
September	Traces A	9	18	14	11	16	20	20	34	24	28	47	50	64	45	50	53	56	37	39	33	30	24	18	17	757
	0.01 or more B	28	31	32	32	34	38	43	39	36	42	57	77	84	112	101	73	68	59	45	29	27	24	25	23	1,159
	Sum, a+b C	37	49	46	43	50	58	63	73	60	70	104	127	148	157	151	126	124	96	84	62	57	48	43	40	1,916
October	Traces A	15	10	16	18	25	28	24	41	31	25	25	37	42	30	31	20	28	31	26	27	22	14	9	9	584
	0.01 or more B	24	31	29	27	29	26	36	24	33	37	37	41	61	55	55	52	51	45	36	27	20	20	27	26	849
	Sum, a+b C	39	41	45	45	54	54	60	65	64	62	62	78	103	85	86	72	79	76	62	54	42	34	36	35	1,433
November	Traces A	10	21	24	19	23	21	31	36	25	31	31	28	39	20	23	28	29	35	21	26	24	36	25	10	616
	0.01 or more B	30	36	27	30	29	40	41	36	37	33	32	40	35	43	37	42	35	26	36	36	35	36	32	39	843
	Sum, a+b C	40	57	51	49	52	61	72	72	62	64	63	68	74	63	60	70	64	61	57	62	59	72	57	49	1,459
December	Traces A	36	42	32	51	46	48	49	57	59	59	49	56	67	51	56	48	44	58	61	57	54	49	60	40	1,229
	0.01 or more B	65	69	77	69	68	72	76	75	66	68	66	65	70	73	70	72	79	65	66	60	65	72	68	65	1,665
	Sum, a+b C	101	111	109	120	114	120	125	132	125	127	115	121	137	124	126	120	123	123	127	117	123	121	128	105	2,894

Whatever may be the true weight of such apparent inaccuracies, the summation of the records of slight rainfalls adds in an important manner to the records of automatically measured rain, and in the main conforms well with and nicely supplements the count of the measurable records.

In going beyond this point to a comparison of the records in different months, we meet a second limitation which must be considered in using the raw data carried in Table 1. The difficulty here, as in the first case, grows out of the necessity for keeping records in artificial brackets, in this instance the varying lengths of the calendar months. Before the hourly or monthly totals for 28, 29, 30, and 31 day months can be accurately compared, some form of correction to secure uniformity must be applied. This is most simply cared for by reducing the number of rainfall hours to a percentage of the total time involved in any grouping. For example, there were 2,894 hours with precipitation, in December. The total amount of time in that month for 30 years is 22,320 hours, and precipitation of a trace or more therefore occurred in 13 per cent of the hours in December. Likewise the 30 years showed 1,213 hours in February within which rainfall of 0.01 inch or more was recorded; this was 6 per cent of the total, 20,304 hours, in that month for the whole number of years.

The count for each individual hour of the day, by months for the 30-year record, was similarly reduced to a percentage of the total number of hours of that name in the month. This base total to which percentages were referred varies from the sum, 846 in February, to 900 for any 30-day month, and 930 for 31-day months. Hourly percentage frequencies for measurable rains, given as round percentages, are shown in Table 2. It was not considered desirable to reduce the hourly records of traces of rain to a percentage basis.

TABLE 2.—*Frequency of occurrence of* ***measurable*** *rain in each hour, expressed as a percentage ratio of rainy hours to total number of same name in the month (New Orleans, La., 1898–1927, inclusive)*

Month	Hour ending—																							
	A. M.											Noon 12	P. M.											Mid. 12
	1	2	3	4	5	6	7	8	9	10	11		1	2	3	4	5	6	7	8	9	10	11	
January	5	5	6	6	7	7	6	5	5	5	6	5	7	6	7	7	7	6	7	5	6	6	5	5
February	6	6	6	6	6	7	6	6	6	6	6	6	6	6	5	6	6	7	7	6	6	6	6	5
March	4	5	4	5	4	5	6	5	5	4	5	5	6	6	6	6	6	6	6	6	4	4	4	4
April	4	4	3	4	3	3	3	4	4	4	4	4	4	5	5	5	4	4	4	4	4	4	4	3
May	3	3	3	3	4	3	4	3	4	5	4	5	5	6	6	4	4	4	5	4	3	3	3	2
June	2	2	1	2	3	3	3	2	3	6	7	10	11	10	11	10	9	7	4	3	3	2	2	1
July	1	1	2	3	3	3	4	3	5	6	9	11	13	14	12	12	8	8	5	4	3	2	2	1
August	1	1	2	2	2	2	2	2	3	5	7	10	12	14	11	10	9	8	5	3	2	2	1	2
September	3	3	4	4	4	4	5	4	4	5	6	9	9	12	11	8	8	7	5	3	3	3	3	3
October	3	3	3	3	3	3	4	3	4	4	4	4	7	6	6	6	6	5	4	3	2	2	3	3
November	3	4	3	3	3	4	5	4	4	4	4	4	4	5	4	5	4	3	4	4	4	4	4	4
December	7	7	8	7	7	8	8	8	7	7	7	7	8	8	8	8	8	7	7	6	7	8	7	7

Coberly's previous paper on this subject (Monthly Weather Review; September, 1914) presented a simple count of frequency of hourly rainfall records of 0.01 inch or more for the nine years, 1905 to 1913, inclusive. No effort was made by Coberly to effect strict comparability of his statistics for the various months. Examination of his data shows that August had markedly fewer hours with rain than did either July or September, although the normal rainfall amount is higher in August than in September, and there is no evident reason for thinking that the prevailing convectional type of rainfall should be less frequent in August than in adjacent months. It was, in fact, this unexpected discrepancy that led to the present study in an effort to arrive at the true frequency by consideration of a longer term of records.

Using the 30 years, 1898 to 1927, both inclusive, gives a body of data which by the length of record covered may be supposed to be more free from the accidental errors resultant from deficient sampling. However, it will be seen in Table 1 that August still shows a slightly lower total of hours (1,118) with measurable rain than does September (with 1,159), although the total of *all* hours including traces is slightly larger for August.

The distribution of measurable rainfall throughout the 24 hours of the day, by months, is represented in Figure 1, in which the percentage frequency of occurrence for each hour, as carried in Table 2, is depicted by radial distance in a circle providing place for each hour in the day. Rainfalls for the hours 6 p. m. to 6 a. m. have, for convenience, been distinguished from those of the other half of the day by distinctive shadings. It will be seen that winter rains are well distributed around all hours of the day. Extreme distortion of the distribution is characteristic of the hot months, when only a minor fraction of measurable rainfalls is recorded between 7 p. m. and 9 a. m.

The rainiest hour of the year at New Orleans, judged by the sum of traces and measurable rains, is the hour from noon to 1 p. m. in July (Table 1) when rain conditions enter the record on about one day in four. The hours between 1 and 2 p. m. in July and between noon and 2 p. m. in August show a frequency of the rain condition nearly as great as in the hour first named. Measurable amounts are most frequently recorded between 1 and 2 p. m. in August, and nearly as often in the same hour in July.

The driest hour of the year is between 1 and 2 a. m., in July, when frequency of the rain condition (including traces) is less than 2 per cent. Frequencies of only 1 per cent for measurable rains are recorded in several of the early morning hours in June, July, and August, when measurable rains are at minimum frequency.

The bias of hourly distribution of rainfall towards the warmer time of the day marks the summer thundershower type of precipitation, which reaches its highest perfection in August, but which is distinctly dominant from May through October, and shows its beginnings in April. The lack of other types of rainfall in August probably accounts for the slight comparative reduction

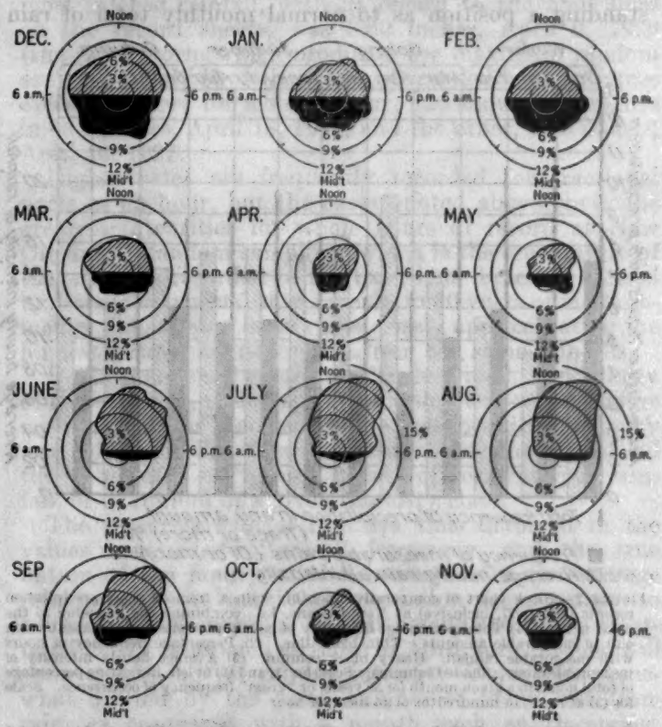


FIGURE 1.—Graphic representation of hourly percentage frequencies of measurable rains at New Orleans, La. (based on records for the 30 years, 1898–1927, inclusive). Circumference of each monthly circle represents the 24 hours of the day, noon at the top. Radial distance along any hour line represents the percentage of total hours of that name in which measurable rainfall occurred. Concentric circles indicate intervals of 3 per cent in frequency values. Areas embracing the interval from 6 p. m. to 6 a. m. (covering night hours) are blocked out in black

in the total of rainy hours in that month as compared with July and September.

The charts in Figure 1 afford a particular emphasis to the characteristic features of rainfall distribution throughout the day in all seasons, but that figure does not present to the eye a proper comparison of the relative *monthly* values of frequency, because values in that figure depend on radial distance—not upon area. April, for example, as compared with December, has about half as many hours with measured rain, but the comparative areas for April and December in Figure 1 are nearly as one to four.

TABLE 3.—*Summary of monthly frequency and mean intensity of hourly rainfall records (New Orleans, La., 1898–1927, inclusive)*

	January	February	March	April	May	June	July	August	September	October	November	December
Total number of hours with only a "trace" of precipitation	1,116	939	863	556	539	738	917	817	757	584	616	1,229
Gross percentage frequency,[1] N/T	5.0	4.6	3.9	2.6	2.4	3.4	4.1	3.7	3.5	2.6	2.8	5.5
Total number of hours with measurable precipitation (a)	1,322	1,213	1,128	850	861	1,046	1,252	1,118	1,159	849	843	1,665
Gross percentage frequency,[1] N/T	5.9	6.0	5.0	3.9	3.9	4.9	5.6	5.0	5.4	3.8	3.9	7.5
Combined percentage frequency	10.9	10.6	8.9	6.5	6.3	8.3	9.7	8.7	8.9	6.4	6.7	13.0
Total rainfall, 1898–1927, inclusive, inches (b)	121.36	126.53	146.98	164.01	142.82	159.45	196.96	171.04	166.98	103.25	85.79	153.87
Average hourly intensity of rainfall ("traces" excluded, and value=b/a)	.092	.114	.136	.193	.166	.153	.157	.153	.144	.122	1.02	.092

[1] Percentage frequency expresses the value of N/T, where T=total number of hours in the month, and N=total number of hours with rain.

Figure 2 was therefore prepared, based upon Table 3, in order to show the relative frequency of hourly rainfall, month to month. In this figure it may be seen that the winter months experience the more extended rains, and four months, April, May, October, and November, are of nearly uniform low standing in percentage of hours with rain.

However, when the total *amount* of precipitation in each month is divided by the total number of hours with measurable rain, it is found that in average rainfall *intensity*, April leads all the months of the year, notwithstanding a position as to normal monthly total of rain

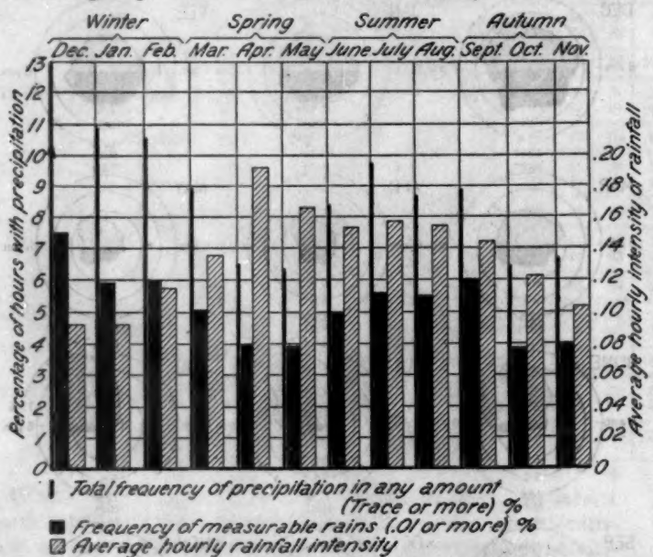

Winter
Spring
Summer
Autumn
Dec. Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov.
Percentage of hours with precipitation
Average hourly intensity of rainfall
Total frequency of precipitation in any amount (Trace or more) %
Frequency of measurable rains (.01 or more) %
Average hourly rainfall intensity

FIGURE 2.—Block chart of comparative monthly values, from 30 years precipitation records (1898–1927, inclusive) at New Orleans, La., combining the following in the order named: (1) Total percentage frequency of hourly precipitation of traces of rain and of measurable amounts. Thin black line. (2) Percentage frequency of hours with measurable rainfall. Heavy black column. (3) Average hourly intensity of measurable rains. Shaded columns. Scale for (1) and (2) at left, indicating percentage of total hours in a given month for 30 years, or "gross" frequency of occurrence. Scale for (3) at right, in hundredths of an inch per hour

which is exceeded by four other months. December and January show the lowest hourly intensities, although neither is the driest month in the year, as three other months carry considerably smaller normals of total rainfall.

These values evidently reflect variations in the character of the rainstorms at different seasons of the year. It is well known to residents of the middle Gulf coast region that the character of winter rains differs materially from the shower type prevalent in warmer seasons, but it is somewhat surprising to find the highest average intensity of rainfall in April (with normal precipitation 4.91 inches) rather than in July, when the normal precipitation total is almost one-third greater and thunderstorms the principal cause of rain.

The fortuitous character of the causes producing rains might be expected to tend (in a large number of random samples such as compose the 30-year record under consideration) towards intensity frequencies which might be classed in an orderly arrangement approximating the uniformity of a section of the "normal distribution curve." The smallest amounts of rain of course occur most frequently, and the largest amounts are most rare; it might therefore be expected that there is a fairly constant inverse ratio of intensity to frequency.

To test this idea the hourly records of measurable rain were grouped in classes, the first containing all

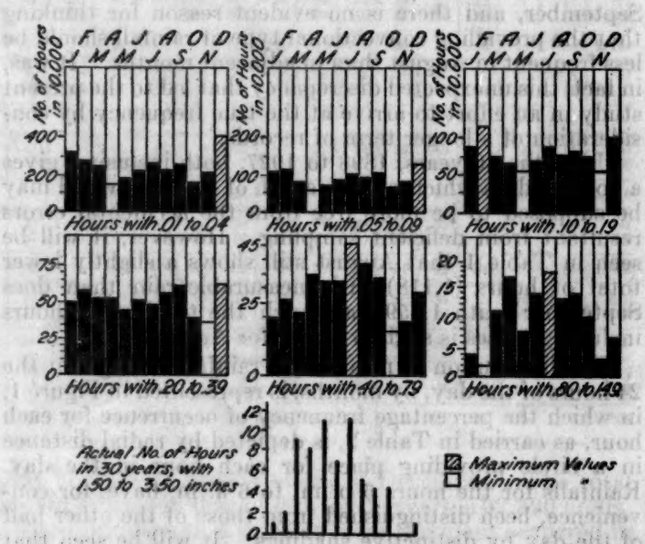

F A J A O D
J M M J S N
No. of Hours in 10,000
Hours with .01 to .04
Hours with .05 to .09
Hours with .10 to .19
Hours with .20 to .39
Hours with .40 to .79
Hours with .80 to 1.49
Actual No. of Hours in 30 years, with 1.50 to 3.50 inches
Maximum Values
Minimum "

FIGURE 3.—Block chart of frequencies and approximate amounts of precipitation in various classes of hourly intensity, by months, as recorded at New Orleans, La., in the 30 years, 1898–1927, inclusive. Hourly intensity class limits shown under each group. Vertical scales at left indicate frequency of occurrence. Except for the bottom group, frequency is expressed as number of hours out of 10,000 (for each month) showing rainfall of given intensity. Vertical scales are expanded (successively doubled) in approximate ratio to the increasing values of successive group intensities. Length of column is therefore comparable, month to month and class to class, to show approximately the *total* amount of rainfall recorded as a result of each intensity

hours showing rainfall of 0.01 to 0.04 inch; the second, those hours with 0.05 to 0.09; the third, records of 0.10 to 0.19; the fourth 0.20 to 0.39; the fifth, 0.40 to 0.79; the sixth, 0.80 to 1.49; and the seventh and last, all amounts of 1.50 inch or over. The limits used for each class increase in approximate geometric ratio throughout the series. Each class after the first covers a range of amount about twice as wide as that of the preceding class.

Section I of Table 4 summarizes the count of these groupings for each month in the year, and, as in other tables, the frequency of each class is expressed (in Section II of Table 4) as a percentage of the total number of hours in the record for each month.

TABLE 4.—*Frequency of hourly rainfall intensities (random samples), classified in increasing values, Section I; relative to time totality, Section II; and also relative to total rainfall hours, Section III. (New Orleans, La., 1898–1927, inclusive)*

Month	(N) Total hours with precipitation of any amount (T or more), 1898–1927	Section I (C) Intensity group totals, 1898–1927								Average intensity over 1.50
		Trace	0.01 to 0.04	0.05 to 0.09	0.10 to 0.19	0.20 to 0.39	0.40 to 0.79	0.80 to 1.49	1.50 or over	
		Hours	*Hours*	*Hours*	*Hours*	*Hours*	*Hours*	*Hours*	*Hours*	
January	2,438	1,116	727	232	199	110	44	9	1	1.62
February	2,152	939	589	223	224	117	53	5	2	1.58
March	1,991	863	575	185	167	119	49	24	9	1.61
April	1,406	556	353	117	145	116	75	36	8	2.17
May	1,400	539	400	142	119	99	73	17	11	1.95
June	1,784	738	502	180	146	109	72	30	7	1.83
July	2,169	917	592	210	192	106	103	38	11	1.74
August	1,935	817	505	197	171	124	87	29	5	1.75
September	1,916	757	532	213	169	132	77	32	4	1.82
October	1,433	584	394	146	163	87	34	21	4	1.88
November	1,459	616	453	148	115	81	39	7	0	----
December	2,894	1,229	933	298	220	134	63	16	1	2.14

Month	(T) Total hours in each month without regard to precipitation, 1898–1927, inclusive	Section II Gross frequency of occurrence, expressed as the percentage value of group totals (C) above, divided by the time totality (T), opposite (Group intensity values as above; column headings, Section I)							Remarks
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	
January	22,320	5.00	3.26	1.04	0.89	0.50	0.20	0.04	----	Percentage values for cases of hourly rains of 1.50 inches or over not given, due to very small number of such cases.
February	20,304	4.62	2.90	1.09	1.10	0.58	0.26	0.02	----	
March	22,320	3.87	2.58	0.83	0.75	0.53	0.22	0.11	----	
April	21,600	2.58	1.63	0.54	0.67	0.53	0.35	0.17	----	
May	22,320	2.42	1.79	0.64	0.53	0.45	0.33	0.08	----	
June	21,600	3.42	2.32	0.83	0.68	0.50	0.33	0.14	----	
July	22,320	4.12	2.65	0.94	0.86	0.48	0.46	0.18	----	
August	22,320	3.66	2.26	0.88	0.77	0.55	0.39	0.13	----	
September	21,600	3.54	2.46	0.99	0.78	0.60	0.34	0.14	----	
October	22,320	2.62	1.77	0.65	0.73	0.39	0.15	0.10	----	
November	21,600	2.85	2.10	0.69	0.53	0.37	0.18	0.03	----	
December	22,320	5.50	4.18	1.34	0.99	0.61	0.28	0.07	----	

Month	Section III Class frequencies relative to total hours with rain. (The hazard of occurrence of a given intensity among all the hours with rain. The figure below is the reciprocal of the value of C/N, in Section I, above, and should be read as "occurring in 1 hour out of" the number given below) (Group intensity values as above; column headings, Section I)								Remarks
January	2.2	3.3	10.5	12.2	22.2	55.5	271	2,438	The *smaller* the number in this table, the *higher* the frequency, which is the reciprocal of the number shown.
February	2.3	3.7	9.7	9.6	18.4	40.5	430	1,075	
March	2.2	3.3	10.3	11.4	16.0	39.0	80	212	
April	2.5	4.0	12.0	9.7	12.1	18.8	39	176	
May	2.6	3.5	9.9	11.8	14.2	19.2	82	127	
June	2.4	3.6	9.9	12.2	16.3	24.8	59	255	
July	2.4	3.7	10.3	11.3	20.5	21.0	57	197	
August	2.4	3.8	9.7	11.3	15.6	22.2	67	387	
September	2.5	3.6	9.0	11.3	14.5	24.9	60	480	
October	2.5	3.6	9.8	8.8	16.5	42.2	68	358	
November	2.4	3.2	9.9	12.7	18.0	57.4	208	----	
December	2.3	3.1	9.7	13.1	21.6	45.9	181	2,894	
GROUP AVERAGES									
Winter (November, December, January, and February)	2.3	3.3	9.9	11.8	20.2	45.0	242	2,230	
Summer (May, June, July, August, and September)	2.4	3.6	9.8	11.5	16.2	22.3	63	242	

Figure 3 represents the frequency in each class by a graphic scale, expressed as the number of hours out of 10,000, for each month, in which precipitation of each class range has occurred. The vertical scale on which frequency is plotted is doubled for each succeeding block after the first, in keeping with the increasing ratio of average intensities chosen as criteria for each succeeding group. This plan permits of comparison of frequencies in each class, month to month, and indirectly, from class to class.

Because the scale of hours bears a fairly close relation to the intensity of the precipitation, the height of each vertical block represents a reasonable approximation to the average amount of rainfall recorded in each class of intensities. Comparison reveals at once that notwithstanding the great frequency of hours with amounts less than 0.10 inch, the major portion of the total rainfall occurs in hours with somewhat higher rainfall intensities. Maxima of monthly frequencies for the lower classes occur in the winter months, up to and including the class with hourly amounts of 0.20 to 0.39 inch. The maxima shift to the warmer months for those classes which show higher intensities. Summer thundershowers evidently favor the production of hourly intensities of a half inch per hour or higher, and March, April, and May, are marked by a noticeable frequency of storms producing hourly intensities of 1.50 to 3.50 inches.

The largest random sample obtained in any single clock hour in the 30 years of record was 3.44 inches, in April, 1920. The highest amount in the 60 minutes of most intense rainfall, without regard to the hour lines on the record sheets, was 3.60 inches, April 9, 1920 (the same storm which produced the maximum random sample). Only two other cases of selected hour extremes exceed 3 inches for a single hour; one shows 3.01 inches in 60 minutes, April 18, 1914, and the other, 3.39 inches, April 16, 1927.

Higher rates are frequently recorded for fractional parts of an hour, but the cases quoted above cover the greatest intensities for whole hours of record at New Orleans. Random sampling (which is the true nature of the amounts recorded in the fixed hour brackets carried by the record sheets) thus reveals, in 30 years of measurements, a maximum hour value closely approximating the highest *selected* hour-intensity from the same rainfalls.

In the frequency studies so far described, the totality of elapsed time, including hours without as well as hours with rainfall, has been used as the base to which frequency was referred. The results measure what may be called the "absolute" or "gross" hazard of occurrence of rainfall, or of rainfall of a given intensity class.

The intervals *without* rain are thus involved in the values assigned to "gross" frequency, and the true nature of the hourly rainfall intensities in the average rainstorm, as it may show variation from winter to summer, or otherwise, is to that extent obscured. Scattered heavy rains such as those of April, for example, will show a sequence of rainfall intensity frequencies somewhat diluted by the great number of hours free from rain, as compared with a month such as December, which has more rainy and fewer dry hours.

To obviate this difficulty is simple. If the sum of all hours with the "rain condition" (as evidenced by records of a trace or more of precipitation) be taken as the base upon which a "relative" frequency for each group intensity is computed the results will display the true hazard of rainfall intensity amongst the hours in which rain actually falls. Seasonal comparison of the sequences of varying hourly intensities is then legitimate, and a truer view of the nature of the average rainstorm in each season is obtainable.

Section III of Table 4 sets forth numerical values for this "relative frequency" of intensity groups compared with total rainfall hours for each month of the year. The numbers used are set down in whole numbers instead

of fractions, or percentages. Each value must be understood as indicating the average number of random samples of hourly rainfall which must be taken to secure one example of the given hourly intensity. A value of 4 for the group "0.01 to 0.04" in April, thus indicates that, in the average, hourly rainfall of 0.01 to 0.04 inch intensity occurs once in each four hours of rain in April. A value of 2,894, for hourly rains of 1.5 inches or over, in December, means that rainfall has exceeded 1.5 inches per hour in that month in only one hour out of nearly 3,000 with rain. The *smaller* values thus represent *higher* relative frequencies.

Casual inspection of the values in Section III of Table 4 reveals several noteworthy features. The uniformity experienced twice as frequently in December as in May, traces provide practically the same proportion of *rainfall* hours in either month, being actually less numerous in May because rainy hours of all other intensities are also less numerous in that month compared with December.

Similar considerations apply to the values for the next two intensity groups, 0.05 to 0.09 and 0.10 to 0.19, which occur with remarkably uniform *relative* frequency at all times of the year.

With the classes of hourly amounts between 0.20 and 0.39 inch, there appears a wider seasonal variation, and in the higher intensities this range increases to a very large ratio, until the last column carries values indicating that hourly amounts exceeding 1.5 inches or over are

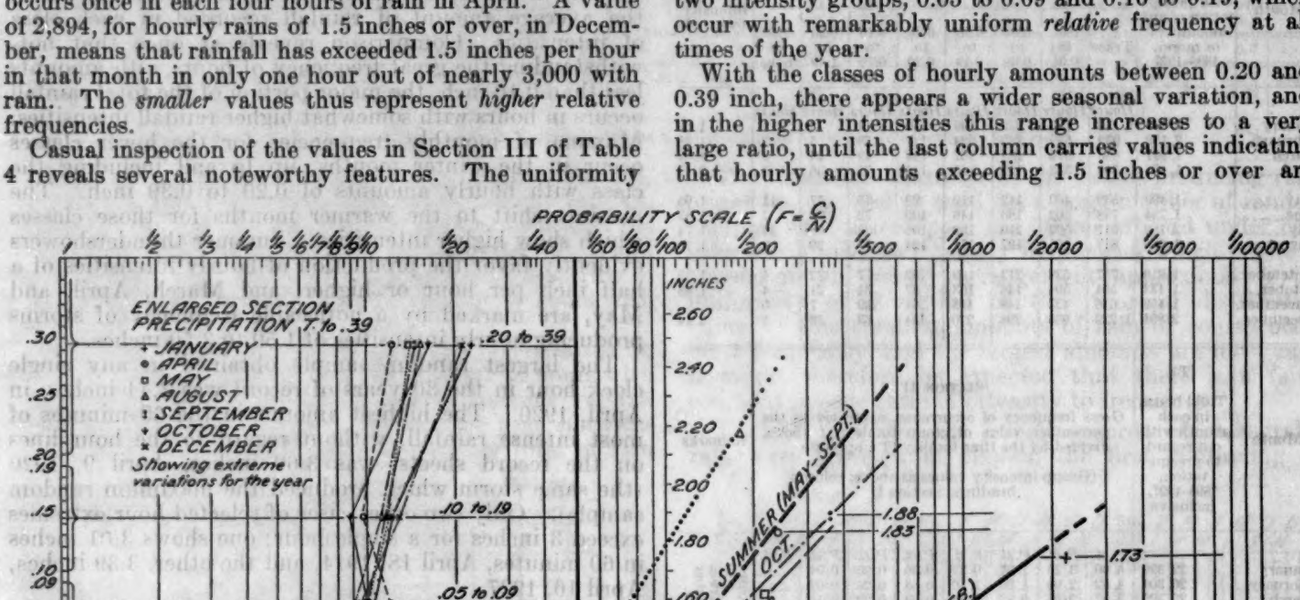


FIGURE 4.—Frequency of precipitation of varying hourly intensity, relative to the total of hours with rainfall of a trace or more, in each period, as shown by records at New Orleans, La., for 30 years, 1898–1927, inclusive. Each month or season is indicated by a curve connecting a series of points arising from relative frequency of each intensity in the month or season. Vertical scale shows values for hourly precipitation intensities in inches and hundredths. Horizontal scale carries frequency values in logarithmic series. Cross lines are placed at midpoint of each intensity class, as representing the approximate average value for each class. The frequency value indicated by vertical line intersecting intensity line at any plotted point expresses the average number of random samples of hourly precipitation required to secure 1 example of the intensity class for which the point is plotted. The fractional form is to be read as "1 example out of" the number in the denominator. Straight line relation of plotted points indicates that the values connected by that line are related as a logarithmic series

of the frequency values in each of the first three intensity groups, considering together all months of the year in each group, is strikingly evident. Traces occur with a frequency range restricted to the small difference between 2.2 and 2.6, regardless of season. That is, considered solely in relation to hours with rain, about 40 per cent (the value of 1/2.5) of all rainy hours regardless of season, receive only a trace of rain. Compare this range of values with the percentage frequency of traces in the different months, relative to totality of hours in the month, shown in the "trace" column of Section II, Table 4, where the range of values is from 2.42 to 5.5, or a difference of somewhat more than 100 per cent of the lesser value. In other words, while traces of rain are actually twenty times more frequent in May than in December. The value of "infinity" for this item in November is resultant from the fact that no case of intensity reaching 1.5 per hour was recorded in that month.

Further interesting and suggestive relations are brought out by studying the trend of frequencies through horizontal groups, that is, the frequency distribution through intensity series describing each particular month of the year. The numerical tables do not afford a suitably obvious display of such horizontal relations, and for that reason Figure 4 was devised to provide graphic representations and comparisons.

This figure is based upon a logarithmic scale of frequencies. The primary reason for using a logarithmic

scale along the horizontal axis, on which frequencies are plotted, is to permit compression of that scale to convenient compass, without loss of detail in the smaller numbers. By no other means could a range of numbers from 2 to nearly 3,000 be plotted with clarity, meanwhile keeping within reasonable space limits.

The secondary, and as results show, the more valuable reason for the use of a logarithmic scale, rests in its important property of throwing into straight line relation, series of values varying by a fixed ratio, which would, under ordinary squared cross-sectional plotting, lie along a curved line. Straight lines and angles are more readily compared than curved lines.

Furthermore, when plotted values group themselves into straight line relations on a logarithmic scale this grouping is in itself evidence of a systematic internal structure in the group, the variation necessarily being in accord with a logarithmic ratio if it fits thus into logarithmic plotting. Straight line grouping of connected frequency values therefore warrants the inference that the events themselves are interrelated as a geometric progression, and are probably resultant from the operation of common causative influences which combine into multiplication patterns rather than the simpler and more heterogeneous patterns of addition. With these considerations in mind the nature of Fgure 4 may be better understood.

The figure is in two parts. A larger section gives representation to full series of hourly rainfall intensity-frequencies, from "traces" to the highest hourly amounts recorded. A smaller section, with the vertical scale expanded to four times its value in the larger, carries frequency-intensities of the lower groups, trace to 0.39 inch, only. The latter is made necessary by the merging of the similar values for these groups, when plotted on the relatively short scale of rainfall intensity used in the larger section. Even with the expanded vertical scale used in the enlarged section, the similarity of relative frequency values for groups of hourly intensity varying from "trace" to 0.09 inch is so great as to practically merge the lines for the several monthly series.

Perhaps the most interesting feature of these graphs is in the fact that the positions for many series of three to five group values, do approximate straight line relations. The frequency values for the low intensity groups not only form individual straight line series for three points, as stated above, but they *all* approximate the same straight line of values, up to amounts of a tenth of an inch of rainfall per hour.

Between 0.10 and 0.39 inch intensities there is a sharp common discontinuity in the frequency series. The rapid rate of decrease in frequencies (indicated by the low angle of the curve prior to that point) suddenly changes, or even in some cases, notably in the values for April and October, increases for frequency of occurrence of 0.10 to 0.19 inch amounts as compared with the number for the group, 0.05 to 0.09 inch.

Thereafter, above 0.19 inch, the series in the main resume satisfactory straight line relations, but with divergent angles of frequency for different seasons. The monthly series for winter (November to February, inclusive) and for summer (May to September, inclusive) were of such uniform trend (see Section III, Table 4) that these groups are represented on the major graph as *seasonal averages*, and not by individual monthly lines.

Slight smoothing of the positions is involved in applying straight lines to these average seasonal frequencies, but this procedure is believed to be justifiable in order to facilitate seasonal comparisons. Naturally, the angle of the winter series is below that for the summer series; this simply reemphasizes the fact already stated, that in winter, the character of the precipitation is such that the larger hourly rainfalls are less frequently recorded, and that in summer, when the convectional type of rain is prevalent, the higher rates of rainfall are more frequently recorded.

The line for April rains lies highest of all after rising above 0.10 inch intensity, and for *five intensity frequency positions, from 0.10 to 2.17 inches per hour, the points are almost exactly in true straight line logarithmic sequence.* The writer considers this a most noteworthy case of a group relation indicative of the operation of consistent underlying causative forces productive of the events so nicely interrelated.

In contrast to the consistency of the frequency curves for winter, summer, and for the month of April, is the irregular grouping of positions representing the frequency series for March and October. Both of these latter curves take a course at first more nearly parallel to the winter type, but, above 0.79 intensity, both rise to a slope more nearly like that for summer. The transitional character of these two months separating winter and summer conditions thus appears to be clear, and a mixture of seasonal influences seems evident in both.

The interesting relations and comparisons resultant from these "relative frequency" studies, just described, invite speculation as to the underlying causes which have produced two discontinuous intensity series in the hourly rainfall at New Orleans. One force or set of forces must have operated in the light intensity range, from trace to 0.10 inch, over which the monthly values agree in producing what amounts to a single line of frequency. Another, distinctly different, factor must come into play to produce the elevation in the angle of frequency lines through the upper range of intensities.

These differences should be explainable in terms of the meteorological processes commonly understood as at work in causing rainfall anywhere. While this problem is too complicated for full attention here, a tentative line of suggestive reasoning is offered.

Obviously, one set of causes operates with considerable relative uniformity regardless of season, to produce the more numerous low intensity samples of precipitation. Superimposed upon these are intensifying factors which begin to operate at rainfall rates of 0.10 inch per hour, and elevate the frequency of production of higher rates of rainfall. Whatever the nature of this second set of factors, it is more effectively at work in summer than in winter, with respect both to frequency and intensity of heavy rainfalls. It finds its highest stage of development in late spring, when the heaviest intensities are relatively most numerous.

It is universally agreed that the most active process of rainfall production is convectional overturning. Secondary to convection in this respect, are the other processes resulting in precipitation, such as the gradual forced elevation of warm air on sliding surfaces only slightly inclined to the horizontal, and cooling by mixture or by radiation.

The latter processes are inherently slow, and reveal none of the violent self-energizing quality that marks convectional overturning. The resultant rainfall must be equally deliberate in rate, and show a very high relative frequency of small amounts of hourly rainfall, with a rapid decrease in frequency for rates above the smallest. The upper limit of intensity of rainfall from nonconvectional causes would appear, from Figure 4, to rise but little if any above the order of a tenth of an inch per hour.

On the other hand, the limit of intensity of rainfall production from convectional overturning is less dependent on the rate of action in the elements of a process than upon the quantity and quality of the supply of warm, moist air and the degree of instability provided before the process begins. Convection is like a conflagration, in that once started it is able to support and extend itself far beyond the initial impulse, through a growth process limited only by factors competent to control the progressive conversion of latent energy into active work.

Small examples will be similar to large ones in that, up to the limit of the energy supply, the process is one of prompt growth from small beginning to maximum possible development. The large examples of convectional overturn may be supposed, in the course of development, to pass through stages of intensity that generally duplicate the characteristics of the smaller disturbances arising under the same seasoned conditions. The by-product of both would be rainfall of similar intensities up to the limits of the lesser disturbance. An intensity series resultant from a collection of samples of convections of all sizes should thus be harmonious within the general limits imposed by seasonal controls.

Colder air, in winter, will set a lower limit of convectional development than that generally obtainable in the warm, moist air of summer. Hence the winter curve of rainfall frequency and intensity lies lower than that for summer.

In the spring the still vigorous cyclonic exchange of polar and equatorial air combines with rapidly rising temperatures and an increasing moisture content of air masses warming near the earth's surface to offer opportunity for development of maximum instabilities. The season favors the conjunction of air currents of great contrast in temperature and humidity, which frequently results in a conversion of general cyclonic energy into the activity of local convections, with rainfall as one of the chief by-products. Thus arise the convectional disturbances of most energetic form, having the largest limits within which their growth can proceed, and thus the curve for April rises to a maximum relation of rainfall intensity to relative frequency.

The largest amounts of rainfall for 24-hour periods occur, at New Orleans, in spring rainstorms (between March and May), in which the quantity of precipitation exceeds even those heavy amounts produced by the passage of well developed tropical storms, which have been responsible for the most intense 24-hour rainfalls in the remainder of the year. The most notable example of the former class of storms is that of April 15–16, 1927, when 14.01 inches of precipitation occurred at New Orleans in one day's rain. The general characteristics of this type of rainstorm are worthy of further study, to place them into correct relation to the major movements of the atmosphere which must attend them.

METEOROLOGICAL SURVEY OF PROPOSED SITES FOR THE SAN FRANCISCO MUNICIPAL AIRPORT[1]

By ERNEST E. EKLUND

[Author's abstract]

Many sites for the proposed San Francisco municipal airport were suggested and the merits of each were discussed at numerous hearings before the Board of Supervisors of the City and County of San Francisco. The opinions of experienced Government and civilian flyers were obtained, but they differed so widely, particularly as to weather conditions, that it was impossible to agree upon a site and it was therefore decided to develop a temporary airport, pending the results of a meteorological survey of all proposed sites, on which to base final judgment in selecting a site for the permanent airport. In cooperation with the city engineer's office, the Weather Bureau was asked to outline the survey and to supervise the work during its progress.

PHYSICAL REQUISITES OF AN AIRPORT

The three primary requisites of an airport are (1) favorable climatic conditions, (2) adequate size, and (3) accessibility. While nearness to the metropolis is desirable, this factor has little weight in determining the best possible location for an airport unless the two more important requirements, i. e., suitable climatic conditions and adequate size, have first been satisfied. The airport must be of sufficient size to provide for buildings and still leave ample room for the operation of aircraft. Runways must be oriented so that planes may take off or land into the wind and they must be sufficiently long to provide a safety factor in the operation of transport planes.

Important as size and nearness are to the problem of airport location, the basic physical requisite is meteorological suitability. Hazards due to weather must be reduced to the lowest possible minimum, which can only be done by choosing the location that has the most favorable meteorological conditions. All other considerations may therefore be disregarded if a proposed location for an airport is unfit for safe landing and scheduled flying because of meteorological unsuitability.

AVAILABILITY OF SITES MEETING REQUIREMENTS

No site within the city and county of San Francisco was suitable for development as an airport. With water to the west, north, and east, the search for sites was necessarily directed southward along the peninsula. Many possible sites were offered and six specific sites were chosen for consideration in the meteorological survey.

Site No. 2 is located just south of what is locally known as South San Francisco, and this location was favored by many because it is nearest to San Francisco. The selection of this location was opposed by others on the grounds that it is bordered by a high tension power line, that rough air is found there owing to the proximity of the San Bruno Mountains and that the site is frequently covered with fog.

Site No. 6 is located 1 mile south of site No. 2 and is the one selected for the temporary airport, known as Mills Field. Those in favor of this location claimed that it is far enough south to escape fog and unfavorable winds attributed to site No. 2 and that it is favorably situated with respect to obstructions. Opponents of this site claimed that more favorable weather conditions would be found still farther south.

Sites Nos. 1 and 4 lie immediately south of site No. 6 and may be considered together since they are separated by the highway only. Site No. 1 is obviously deficient

[1] Complete report, with tables and figures, is on file at Weather Bureau Office, San Francisco, Calif. It is expected that it will later be published in full as a public or private document.—E. E. E.

because of its restricted area and the proximity of the power line, and for these reasons is inferior to site No. 4. Proponents of these sites claimed for them more favorable weather conditions that would be found at sites farther north and that they were more suitable than sites farther south on account of being nearer to San Francisco.

Site No. 5 lies to the northeast of the city of San Mateo and is entirely under water at the present time. Superior climatic conditions were claimed by the proponents of this site, while excessive cost of development, proximity of the power line and remoteness from the city were among the objections.

Site No. 3, located at Beresford, is the farthest south and farthest inland from San Francisco Bay. It was therefore claimed that there is less fog in this locality. Opponents of this site pointed out that its area is inadequate and incapable of extension, that planes would be taking off over well-settled territory and that it is unnecessarily far from San Francisco.

Granting that each of the proposed sites possessed two of the three primary requisites for an airport, i. e., that each was of adequate size and that each was sufficiently close to the center of urban activity, there remained the vital question of suitable climatic conditions. Which one excelled in this respect?

Statements relative to weather conditions along the peninsula could not be supported by any tangible facts or figures because no data were available for any of the sites under consideration. The statements, then, represented only opinions which might be erroneous or biased. The conclusion was reached that the only rational way to decide the matter was to make weather observations at all the proposed sites for one year and let the facts speak for themselves.

METEOROLOGICAL CHARACTERISTICS AFFECTING AVIATION

Among the meteorological elements that affect the operation of aircraft, fog presents the greatest menace. It is therefore obvious that the less fog an airport has, the better is it adapted for commercial use. On many afternoons during the summer, a "blanket fog" forms over the ocean off San Francisco. As the afternoon advances, the fog bank moves landward, is forced to ascend, and lies along the summit of the highest range of hills in the San Francisco Peninsula. If this fog moves inland during the afternoon or night, it is commonly referred to as "the fog coming in," even though it may be, and usually is, 500 to 1,000 feet above the surface of the earth. The formation is therefore stratus cloud and not fog unless it descends to the earth's surface.

Horizontal visibility is a meteorological factor to which little importance was formerly attached but which has become increasingly important with the development of commercial aviation. Visibility defines the visual limits imposed by fog, haze, smoke, dust or precipitation and, especially in the vicinity of an airport, good visibility is desirable.

Ceiling is the altitude of the cloud canopy when the sky is largely or entirely covered; a measure of vertical visibility. If the clouds are very low, they constitute a menace to aerial navigation second only to dense fog, and low ceilings near an airport should be avoided if possible.

Instrumental equipment for observing surface weather conditions at meteorological stations other than the one at Mills Field consisted of an anemograph, sunshine recorder, and rain gauge at each station; the headquarters station at Mills Field also had a barograph sling psychrometer, and maximum and minimum thermometers. Because of the importance of records of fluctuations in wind velocity and direction in considering an airport site, Dine's anemographs were chosen for the meteorological survey and continuous records of wind velocity and direction were thus secured. The sunshine recorders were of the spherical lens type in which the record is burned on a strip of cardboard. Sunshine is of no importance in itself so far as airport operation is concerned but the sunshine records were used in connection with records of fog and cloudiness. The 8-inch rain gauges, maximum and minimum thermometers, sling psychrometer, and barograph were all of the ordinary type.

Noninstrumental observations were taken daily at approximately 9 a. m. at each of the outlying stations, noting the amount and kind of clouds and their direction, the height of the ceiling, if any, the range of visibility, and the occurrence of rain, fog, smoke, haze, etc. Hourly records of all these phenomena were kept at Mills Field.

Aerological observations formerly conducted at the San Francisco office of the Weather Bureau were transferred to the airport and served the dual purpose of providing information for the Weather Bureau and for the meteorological survey. The two-theodolite method was used in the balloon observations for the survey, the readings being made at half-minute intervals in order to obtain more detailed information. The demands of the survey required observations at several sites in rotation and it was necessary to devise a means of transporting the personnel and equipment from place to place and also provide for filling balloons in the field. Equipment for inflating the balloons and specially constructed boxes for transporting the theodolites were installed in an automobile which was also used for making the daily round of the stations. Other perliminary work included the devising of forms for compiling data, the building of a theodolite observation platform, installation of telephones, the erection of an instrument shelter and rain gauges, clearing of firebreaks around the outlying meteorological stations. selection and surveying of 10 base lines for two-theodolite observations in five different locations, and the installation of four anemographs and four sunshine recorders.

Direction, speed, and gustiness are the three factors in surface wind forces that must be investigated before choosing the location of an airport. Turbulence of the air over and near the airport must also be considered. The layout of buildings and runways is determined by reference to the prevailing wind direction, and movements of the air affect not only the ease of operation of an airplane but the safety of the operation as well. Wind direction determines the direction in which a plane is taken off or landed. In either case, the plane is headed directly into the wind. The orientation of the principal runway should be such that it will permit the maximum number of take-offs to be made over favorable territory where a pilot will have a fair chance of landing with a "dead stick" if necessary. When a large number of planes are using the field, frequent shifts in wind direction cause some to be landing or taking off in one direction and some in another, and the possibility of collision is increased. An airplane in flight depends for its dynamical support upon its speed in relation to the air and a moderate wind is therefore an advantage when either landing or taking off, providing it is steady in direction and velocity.

The air is a gaseous fluid which is constantly in motion with whirls, eddies and all sorts of eccentric motions occurring within it in much the same manner as in flowing water. These irregular motions constitute turbulence, a phenomenon that makes its appearance in fluids,

gaseous or liquid, when they flow past solid surfaces or even when two streams of the same fluid flow over or past one another. Changes in the horizontal component of wind movement at the earth's surface are much larger than changes in the vertical component, and these horizontal changes constitute gustiness, the relatively small changes in the vertical component being ignored. Turbulence of the air is of no consequence at high levels but is inimical to ease and safety of flying at low altitudes.

Rain affects the landing surface of an airport and decreases visibility but, in the San Francisco Bay region, records of rainfall and temperature are chiefly of value to the engineer in planning drainage and heating facilities. Thunderstorms are inconsequential in this region.

ORGANIZATION AND EQUIPMENT OF SURVEY

The purpose of the meteorological survey was to collect data that would indicate, from a climatic standpoint, which of several proposed sites was most suitable for airport purposes. It was therefore necessary to investigate and keep records of those meteorological elements which most affect the successful operation of a modern commercial airport. It was the first survey of its kind. Some cities, without preliminary investigation of meteorological conditions, have chosen unsuitable locations for airports; sometimes there has been only one possible location.

The personnel comprised four men; two employed by the city and two by the Weather Bureau. The latter were assigned to Mills Field to perform the aerological and airways duties incident to the status it then held as the terminus of the air mail lines, and other services in connection with the survey were incidental to their official duties at the airport. Had it not been for the cooperation of the Weather Bureau, the meteorological survey of proposed airport sites would have been impossible. The Chief of the Weather Bureau approved the cooperation of Federal employees, allowed the use of instrumental equipment, and selected the meteorologist who conducted the survey. The closest possible cooperation was maintained between the San Francisco office of the Weather Bureau and the city's meteorological personnel.

AIRPORT SITES AND METEOROLOGICAL STATIONS

The six proposed sites included in the meteorological survey lie on the east side of the San Francisco Peninsula in a narrow strip 10 miles long. The topography of the peninsula has marked local influences on the behavior of fog and wind, the two climatic factors that are most significant in determining the best possible location for an airport. Numerous ranges of hills extend along the peninsula, the axes of all the main ridges lying in a northwest-southeast direction. Between two of these ridges is a gap which constitutes the lowest path across the peninsula, wherein the elevation of the land averages less than 100 feet, with hills rising to elevations of 500 to 1,300 feet on either side.

The climate of the San Francisco Peninsula is characterized by mild temperatures, abundant sunshine, marked wet and dry seasons, and frequent summer fogs of marine origin. The prevailing drift of the surface air is from west to east and the velocity of the westerly winds is greatly augmented on summer afternoons by the radical difference in density between the cool, ocean air and that of the heated interior. In addition to the high fog or stratus cloud layer so frequently present on summer mornings, radiation fog sometimes occurs in the San Francisco Bay region during the winter.

In order to obtain data on which to base a comparison of the several sites from the standpoint of meteorological fitness, it was necessary to establish four meteorological stations. The headquarters were at Mills Field, or site No. 6, and data secured there were also used as an index of weather conditions at the two adjoining sites, Nos. 1 and 4. The wind vane was placed on a 20-foot mast mounted on the roof of the building, with the thermometer shelter, rain gauge, and sunshine recorder in suitable locations outside. Each of the three other meteorological stations included a house 8 feet square and 10 feet high with the anemograph support and sunshine recorder on the roof and a rain gauge on the ground nearby. These stations were located on sites Nos. 2, 3, and 5. Five locations were selected for making 2-theodolite pilot balloon observations and a pair of base lines was laid out in each location, one pair serving for two sites, Nos. 1 and 4.

RESULTS OF INVESTIGATIONS

In presenting the results of the investigations made during the year, each meteorological element was considered in its relation to each of the several proposed sites, the sites being weighed in geographical order from north to south. Although continuous records of the various meteorological elements were made at Mills Field, continuous records for other stations were available only for those elements which were recorded by means of automatic instruments. The results of the daily observations were used as a basis for comparing those meteorological elements that were recorded from eye observations. Fog was recorded from eye observations but the sunshine records were used to supplement these in indicating the time the fog began or ended. Dense fog was observed at sites Nos. 1, 4, and 6, 8 times in 295 observations and at each of the other stations 9 times. Fog was observed at one or more stations on 14 dates and four types of fog distribution were represented, which we may call general, northern, southern and local.

Owing to the observational limitations of the survey, it was necessary, in order to make a comparison of fog conditions at the several proposed sites, to adopt some number system as an index of relative fogginess. Numbers were assigned to indicate the order of dissipation of fog at the several sites and, considering all fogs observed, site No. 6 proved to have less fog than any of the others by the ratios 18:27, 18:23, and 18:27. Further comparison was made by totaling the duration of all fogs after 7 a. m. It was found that in most instances fog dispersed at site No. 6 earlier than at the others and that the total duration of fog was least at that site.

Visibility as determined at the daily observations was represented graphically and in tabular form, by days and months, and the records made at site No. 6 indicated somewhat better visibility than did those made at any other proposed site.

A scale was adopted for indicating ceiling, as follows:

O------ Surface (dense fog).
A------ Less than 500 feet.
B------ 500 to 1,000 feet, inclusive.
C------ Above 1,000 feet.
U------ Unlimited.
X------ Broken.

From the daily observations and from the sunshine records, it was found that on summer mornings the clouds dissipated earliest at the most southerly site and latest at the most northerly, but that during the winter there was little difference in the height of the ceiling at the several suggested sites.

Continuous records of wind direction were tabulated hourly to 16 points of the compass at all four meteorological stations. The percentage of time the wind blew from each direction was computed. It was discovered that the wind direction at site No. 6 was more constant than at any of the other proposed sites. Since more flying is done in the daytime than at night, the prevailing direction for each site, shown in percentage of time, was computed for the period 6 a. m. to 6 p. m. and it was ascertained that constancy of wind direction during the daytime was more marked at site No. 6 than at any of the others and that, in general, the directions were similar to those prevailing for the entire 24 hours. The greatest freedom from sudden changes in wind direction was found at site No. 2, where the average maximum abrupt change in wind direction was 38°; at sites Nos. 1, 4, and 6, 43°; at site No. 5, 45° and at site No. 3, 92°. Sudden changes in wind direction as large as 135° occurred frequently at site No. 3.

From the automatic records of wind velocity, it was learned that winds from the WNW. had the highest average velocity. During the summer months, wind velocities increased shortly before noon when the sea breeze began to blow and reached their peak at about 4 p. m. Wind movement averaged greatest at site No. 2, followed in order by site No. 5, sites Nos. 1, 4, and 6, and site No. 3. Extreme wind velocities were tabulated for each hour and the proposed airport sites ranked in order from north to south as regards freedom from high wind velocities.

Excessive gustiness of the wind being an undesirable feature in an airport, a knowledge of maximum amplitudes of quick fluctuations in wind velocity and of sudden changes in wind direction was required for each site. Gustiness in winds of less than 10 miles per hour was ignored. Data on maximum amplitudes of rapid fluctuations in wind velocity were obtained by considering such a fluctuation to be represented by the longest vertical line registered during each hour on the anemograph sheets, and it was assumed that the record made by a vertical line would occur within the period of time that would embrace the landing or take-off time of an airplane. Maximum fluctuations for each hour were tabulated and monthly averages of gustiness due to rapid fluctuations in wind velocity were computed.

Maximum fluctuations in wind velocity, however, do not present a complete index of gustiness so far as its effect on airplane manipulation is concerned because quick variations in wind direction, even when unaccompanied by changes in velocity, have an effect on an airplane in flight comparable to fluctuations in wind velocity, depending upon the amplitude and suddenness of the variation. Assuming that a change in direction as indicated by a vertical line on the anemograph sheet occurs practically instantaneously, if V is the mean wind velocity and A the angular change in direction, the effect of A will be the same as a change in velocity equal to $V(1-\text{Cos } A)$, of gustiness $(G)=V(1-\text{Cos } A)$. Monthly averages of gustiness (in m. p. h.) due to sudden changes in wind direction were computed.

Considering gustiness induced by both causes—i. e., that due to velocity changes and that due to direction changes—the least average gustiness occurred at site No. 5, 6.2 m. p. h., followed by sites Nos. 1, 4, and 6, 6.5 m. p. h.; site No. 2, 6.9 m. p. h. and site No. 3, 10.8 m. p. h.

Turbulence involving air movements with marked vertical components at ordinary flying levels may be inferred by means of pilot balloon observations in which two theodolites are used. The ascensional rate of 180 meters per minute was used because it was necessary to combine the two-theodolite observations for the use of the survey with the single-theodolite observations required by the Weather Bureau, and departures from this rate could only be due to turbulence. Departures from the normal ascensional rate were determined for each half-minute period. The least average variation from the normal ascensional rate, and hence the smoothest air, between the surface and the 1,000-foot level occurred over sites Nos. 3 and 6, while above the 1,000-foot level the greatest freedom from turbulence occurred over site No. 6. The strongest vertical air current that was found was downward (3.8 m. p. s.) over site No. 2 at an altitude of 3,700 feet.

Slight variations in precipitation were found at the various sites. By comparison with records for San Francisco, it was estimated that precipitation for the year was somewhat subnormal and that the temperature averaged a little above normal.

CONCLUSIONS AND RECOMMENDATIONS

It was shown that fog occurred fewer times at site No. 6 than at any of the other proposed sites, that the total duration of fog after 7 a. m. was least there, and that, on the average, site No. 6 had the best visibility. Site No. 3 possessed an advantage over the more northerly sites as regards the duration of low ceilings in summer. Constancy of wind direction was most pronounced at site No. 6, and a runway oriented according to the prevailing wind would permit the maximum number of take-offs to be made over favorable territory, which would not be true at the other proposed sites, excepting No. 4.

Variation in wind direction from moment to moment at site No. 6 was less than at any other proposed site except No. 2. The surface wind velocity at site No. 6 was more advantageous for the operation of aircraft than at site No. 2 and equally with site No. 5, although smaller average wind velocities and greater freedom from high winds occurred at site No. 3. The latter site had a distinct disadvantage on account of excessive gustiness. No other proposed site had less turbulence than site No. 6.

All factors considered, no other suggested site appears to have as favorable meteorological conditions as site No. 6, and this site, the location of the temporary airport, is therefore recommended, as a result of the meteorological survey, as the most suitable one for the permanent location of the San Francisco municipal airport.

FATHER E. GHERZI, S. J., ON A STUDY OF THE RAINFALL OF CHINA[1]

By ALFRED J. HENRY

Father Gherzi's work is in two parts and an atlas of charts. Part I contains summaries of the available statistical matter and the discussion and Part II contains the observations from 198 stations for each month and the year. The atlas contains 34 charts of monthly seasonal and annual values on maps 11½ by 17⅜ inches. (29.2 x 44.2 cm.)

I quote the following from Father Gherzi's foreword to Part I:

The work here presented to the public can not be considered as definitive. The number of stations [2] is too limited to furnish for a region so vast as China results that are both general and detailed.

It is necessary, first of all, to justify this attempt at generalization of the distribution of precipitation over China knowing that it is based on data that are relative incomplete.

In 1911 Father L. Froc published a research on the rainfall in China during a period of 11 years (*La pluie en Chine, d'après une periode de 11 années.* Changhai) and at the same time expressed his entertainment of hope for a more complete publication on the same subject.

At that time, when young China seemed willing to enter the path of scientific research through reorganization of government, it was hoped that in 10 or 15 years the number of meteorological stations, maintained by the Government or otherwise, could be increased tenfold and, with the network of the stations of the customs service, could thus furnish very complete data for an exhaustive study of rainfall in China.

Events since 1911 and present serious conditions have removed that flattering hope to the far distant future. It is for that reason and in order not to delay too long the publication of data that will be very useful to numerous public services that the work is now presented.

Despite the fact that there are regions for which there are no data it is believed that the charts will be truly useful, and will furnish for some regions information that is important and even definitive.

The network of the stations of the customs service while much less close than that of certain conservancies, such as the Chihli River Commission, is much older. The data extend over several decades and there is uniformity in instruments, which partially compensates distribution over extensive regions. These data permit one to trace with assurance the principal curves on the charts accompanying the tables.

The stations of the conservancies [3] are more recent. We have omitted publication where the record is for only one year, but have made use of the values in drawing certain isohyets in regions of our charts where no stations are entered.

The stations of the Chihli River Commission although more recent than the majority of the stations of the customs service form a well equipped network, so close that it has been considered proper to detail the results in a series of special charts. We could not attempt such work for other interesting regions, for example that under the Yangtse River Commission.

The purpose in view has been to give a general survey of the distribution of precipitation and days with precipitation over China based especially on the long series of observations at stations of the customs service. This appears to have been attained rather well.

We have used a larger number of curves than is usual in such researches; this seemed useful in order to give a graphic representation of what may be called the "precipitation gradient" (*gradient pluviométrique*) for the different months of the year. This gradient is related to important facts: Torrential rains in certain regions, sudden rises in large rivers and their tributaries, and floods. In addition the gradient indicates the regions more interesting for detailed study with a view to the construction of dams or levees.

The utilization of these rainfall details would require observations on relative humidity, temperature, evaporation, and nature of the terrain, which we have not been able to obtain. The curves will, at least, indicate where it would be most advantageous to establish stations for the study of these elements.

The statistical data given in Part II of the work are used in the following manner. The method of consideration employed by Father Froc appeared very interesting and also contributed information such as is desired by the engineers who will use this work, so for those reasons we have retained it, using the more extended series of observations.

It is obvious that certain values and certain conclusions will be different from those based on the series of observations extending over the period of 11 years to which the former study was limited. There have been added to the tables analysis of charts, data on storms, snow and hail at different stations, and also a discussion of the causes of rainfall and rainfall periodicity in China.

In the matter of the location of the rain gauges it appears sufficient to give the approximate latitude and longitude of the station with the details previously published by Father Froc. There has been frequent discussion as to the best exposure for a rain gauge, in regard to removal from neighboring objects and height of the receiver. It can not be stated that all of the instruments whose records have been used are exposed under the best possible conditions. No; it can be stated, however, that at all times and in all places there has been an attempt to attain the ideal.

It is well to state that the instruments in use are of two types: The 8-inch gauge (Negretti-Zambra evidently this is the type known as the "Meteorological Office" rain gauge with 8-inch diameter and graduated glass measure of one-half inch capacity) placed near the ground (equipment at stations in the Customs Service) and that sometimes called the Zi-ka-wei gauge in the conservancies—the model adopted for field in the United States and in the Philippine Islands, and which appears to be very advantageous in places where it is difficult to obtain measuring glasses, as at the present in the provinces of China.

Unfortunately, in all of the vast region of China there are only three places where recording rain gauges are in operation: Hong Kong, Tsingtao, and Zi-ka-wei.[4]

In this connection it will be noted, to our great regret, that in the list of rainfall stations there are missing stations strictly Chinese that is, stations at universities and schools. Although the installation of a rain gauge is a simple matter, it must be acknowledged that the patience to observe and record is still lacking in those who would find interest in meteorology. We regret that the 1,500 stations which the director of the *Observatoire Central de Péking* promised immediately are not organized.

OBSERVATIONAL MATERIAL

Father Gherzi divides his observational material into two groups, one of fundamental stations of which there are 60, and another of secondary stations to the number of 109. The fundamental stations are those maintained by the customs service of China and extend back in a few cases to the early eighties; the observations at most of the customs service stations are continuous. The mean monthly, seasonal, and annual values are given for both groups of stations. I have computed from the fundamental stations the mean monthly, seasonal, and annual precipitation for China as a single geographic unit, and give the values (in millimeters) for what they are worth in the paragraph below. The fractions of a millimeter have been rounded off.

January	28	August	164
February	45	September	119
March	66	October	65
April	100	November	40
May	122	December	28
June	173		
July	169	Annual	1,119

The secondary stations furnish results from 109 places in China variously distributed throughout the provinces. The observations at these stations are due to the efforts of various boards and commissions and to religious organizations, mostly of the Roman Catholic Church. Nearly all the records at the secondary stations are recent and for but a few years. The continuity of the records is not of the best.

[1] Etude sur la pluie en Chine, Changhai, 1928.
[2] Including stations recently established in the valley of the Hwai, the number is 240.
[3] The Yangtse River Commission and, especially, the Hwai River Board.
[4] The gauge installed at Peking has furnished some interrupted records.

THE CAUSES OF RAINFALL IN CHINA

Father Gherzi considers the two great causes of precipitation in China to be the movements of extratropical and tropical cyclones, or typhoons as they are called in that part of the world, and the régime of the two monsoons, the winter, and summer monsoons of eastern Asia. The number of barometric depressions that form in west and central China is relatively great. The total number for 25 years corresponding to the several paths followed by them is given in the following table. The author distinguishes seven paths, the last being the most northern one for which complete data are not available. Storms following this path descend from Siberia and curve to the east and northeast over the Liaotung peninsula. Table No. 1 follows; path No. 1 is in the south.

TABLE NO. 1.—*Number of extratropical cyclones which have traversed the different paths in central and east China (last 25 years)*

Path	January	February	March	April	May	June	July	August	September	October	November	December	Annual
No. 1	10	13	18	12	11	4	1	1	1	2	2	7	82
No. 2	17	12	14	10	9	7	2	4	1	5	3	4	88
No. 3	21	19	21	19	14	9	1	1	4	4	6	8	127
No. 4	13	5	15	16	14	15	2	4	4	7	8	10	113
No. 5	14	11	21	26	24	26	8	3	4	10	16	17	180
No. 6	20	10	18	19	16	12	8	3	4	6	11	12	139
Average	3.8	2.8	4.3	4.1	3.5	2.9	0.9	0.6	0.7	1.4	1.8	2.3	29.1

I present in Figure 1 the mean paths of extratropical and tropical cyclones which influence the rainfall of China. The base map used shows also the Provinces into which China is divided. I am indebted to Dr. O. E. Baker of Clark University and the United States Department of Agriculture for this map. It is not possible to show the place of origin of the tropical cyclones that strike the China coast, but it may be said that they can be traced back over the Pacific far beyond the one hundred and forty-fifth meridian east of Greenwich and close to but probably a little south of the tenth parallel of north latitude.

From the figures of Table 1 it may be seen that the average number of extratropical cyclones traversing central and eastern China is 29 per annum and that the months of greatest frequency are March and April. If a correction be applied to these averages on account of the unequal length of the months, the greatest frequency will still be in those months.

It may be remembered that the great Siberian anticyclone of winter has practically disappeared by the end of March and that a transition to lower pressure over all of central and eastern China is now taking place. Doubtless the increase both in the number of extratropical cyclones or continental depressions and the precipitation is more or less directly related to the changing pressure distribution of the spring season over central China.

It is rather difficult to evaluate the influence of extratropical cyclones on the precipitation of China. Father Gherzi prefers to call them "continental depressions or extratropicals," evidently to emphasize the fact that a cyclonic circulation is not always present and even when present is mostly weak, although at times strong circulations and steep gradients develop especially when the extratropical cyclone reaches the coast.

An examination of the daily weather charts for China and the Far East clearly reveals the predominant influence of the great winter anticyclone of Siberia which often overspreads China and equatorward to the Tongking Gulf. This fact alone is sufficient explanation of the absence of vigorous cyclonic storms in China in the cold season and the sparse rainfall of northern China.

Weather Bureau Bulletin A[1] based on 10 years observations shows that the chief path of extratropical storms around the North Pole starts about the southern tip of Japan in north latitude 30°, passes thence northeastward crossing the Pacific almost parallel with the fifty-second degree of north latitude, continuing thence across the continent of North America close to the forty-eighth parallel of north latitude to the North Atlantic about the fiftieth meridian of west longitude where it bifurcates the greater number of the storms, takes a more northerly course crossing Iceland and again dividing a portion disappearing west of Nova Zembla and the larger portion in the neighborhood of the Urals in eastern Russia. The southern branch from the Atlantic passes into Europe over France, skirts the Mediterranean, and the storms mostly disappear about the Black Sea. Thus there is a hiatus in the path of these storms in their course around the globe. The distance between the eastern termini and the Pacific track is about 90° or a quarter of the circumference of the globe. This summary also shows that May is the one month of the year in which at least one or more extratropical cyclones can be plotted in each 10° square around the globe with the exception of that one between 50° and 60° north latitude and 130° to 140° east longitude, the region of mountains in northeast Siberia facing the sea of Okhotsk.

Fully developed extratropical storms rarely cross the Urals although the free-air portion of the storm may survive and again reach contact with the surface farther eastward and southward as happens at times in the United States. Even those storms that move southeastward via the valleys of the Ob and Yenisei are mostly in a dying condition and seldom pass as far inland as Lake Baikal. The few exceptional storms that survive and pass southeastward from Baikal over Mongolia to the plains of north and central China recurve to the northeast as illustrated in Figure 1 by the unnumbered path at the top.

In the cold season any development of a depression over China is almost immediately followed by a fresh incursion of cold northerly winds from Siberia, hence the small precipitation in north China of that season. In the warm season when pressure over China is relatively low vertical convection becomes active and heavy showers fall at times.

The order of the paths as given in Table 1 is from south to north as can be seen from Figure 1 and it will be noticed that the origin of path No. 4 is identical with that of No. 5, storms following the last named track having more of a northerly component than those of path No. 4.

The origin of extratropical cyclones in central and east China as given by the author is considered as indicating his belief that the points so indicated represent the true origin of the storms so far only as present observations are concerned; it should be remembered that the absence of meteorological observations to the westward precludes the possibility of determining the exact place of origin, moreover, most if not all of these extratropical cyclones may be secondaries that develop from a primary that is passing eastward in latitudes north of the present field of observation.

[1] Summary of International Meteorological Observations by H. H. C. Dunwoody, Washington, D. C., 1893.

TYPHOONS

Typhoons contribute largely to the rainfall of China. The distribution of typhoon rainfall varies with the month of the year and according as the typhoon continues to move toward the northeast or fills up in place.

The dashed lines—typhoon paths—in Figure 1, show the points on the Chinese coast where typhoons on the average, most frequently strike. The table below gives in addition the number of typhoons in 31 years that reached the land or traversed the various Provinces in the south and east of China.

The figures of the above table show quite clearly that the main onset of the typhoons begins with July in the Province of Kwantung and continues throughout August and September, also that the peak of the monsoon season is reached successively later on the coast of China north of Kwantung. The number of typhoons in a season also diminishes with increase in latitude.

Seasonal rainfall distribution.—Winter is clearly the time of least precipitation of the year especially to the north of the Yangste and December is the month of least precipitation in the majority of provinces. At this time

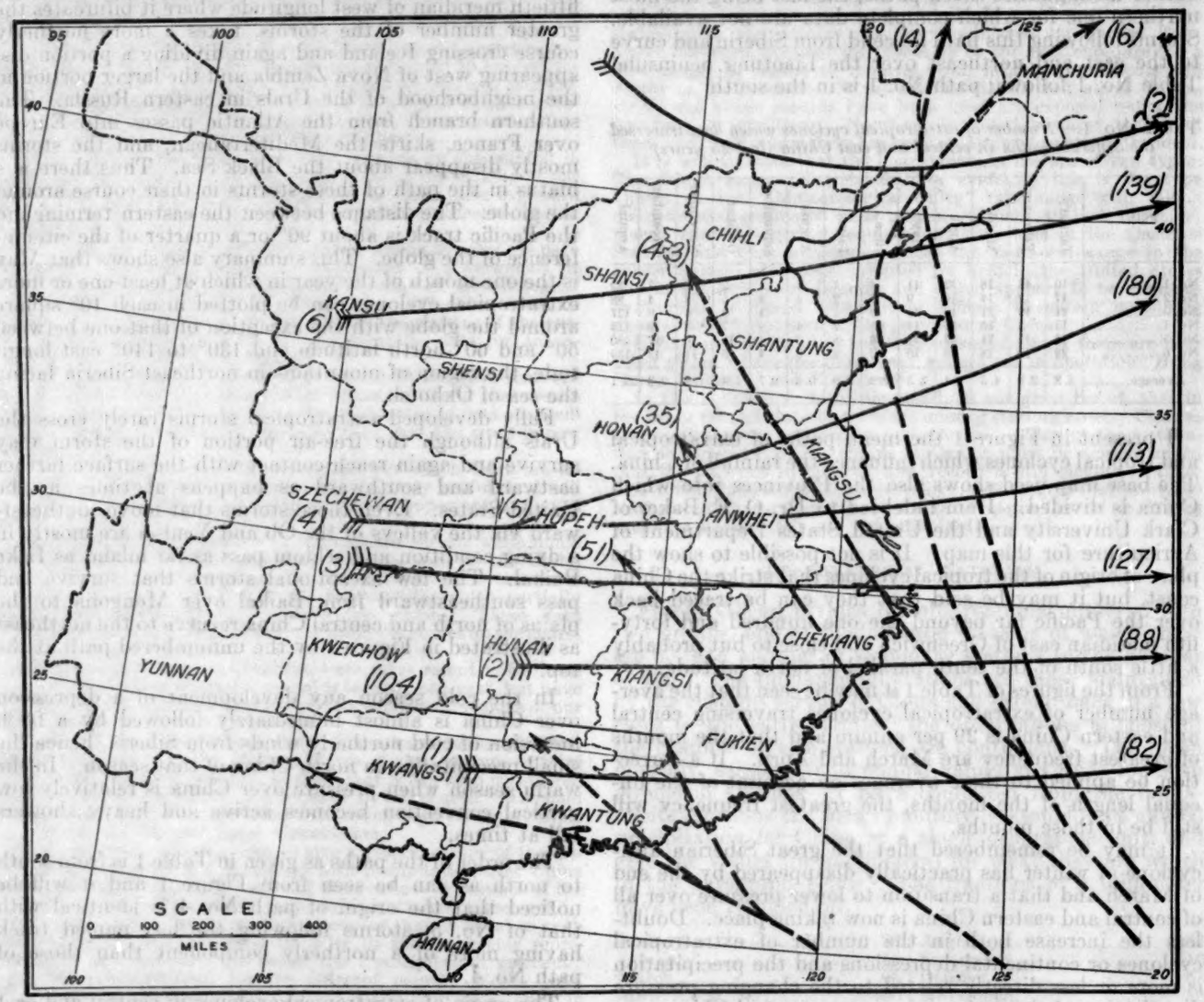


FIGURE 1.—Distribution and tracks of continental depressions (full lines) and monsoons (dashed lines) that traverse China. (After Fr. Gherzi, S. J.)

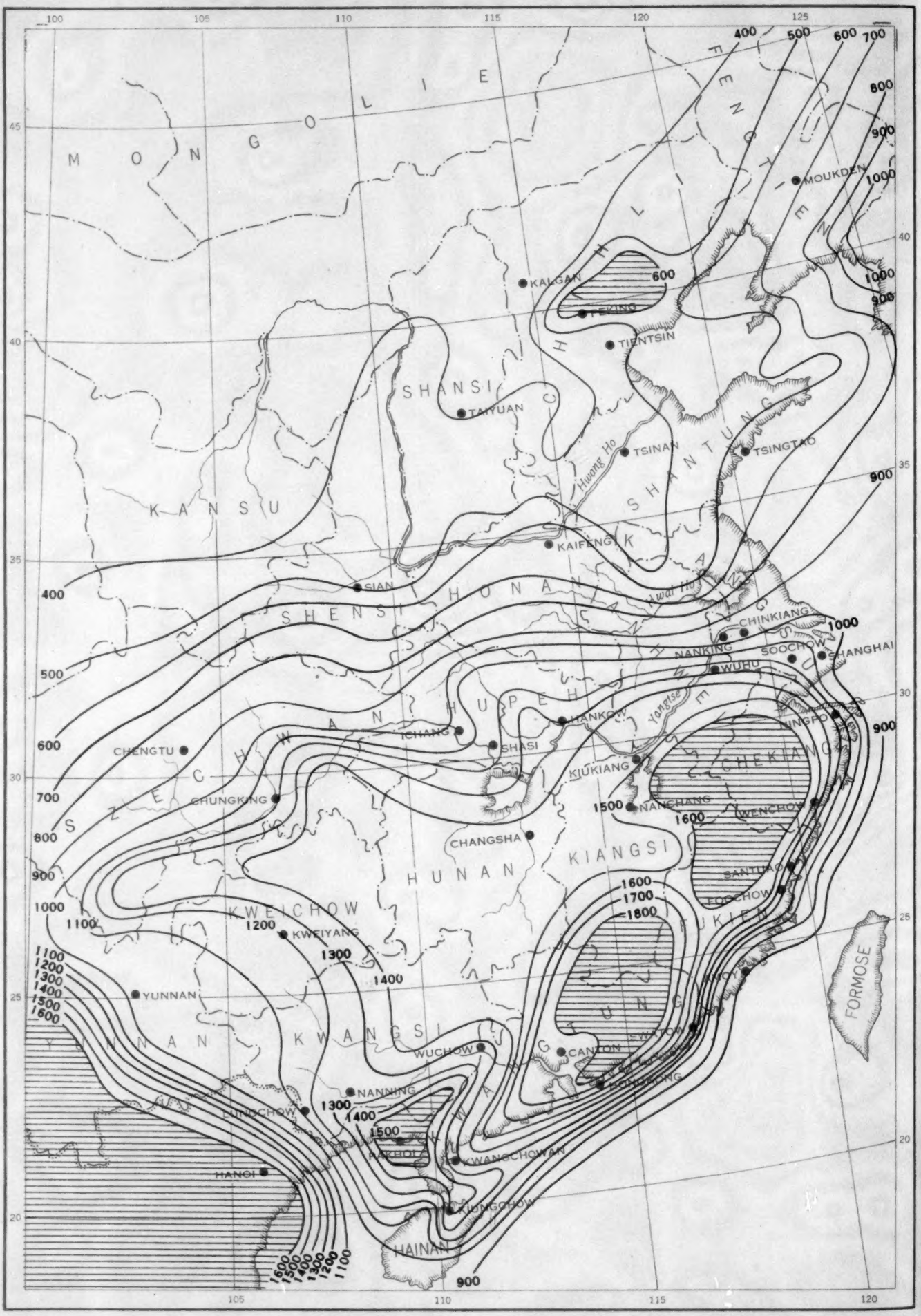
TABLE 2.—*Number of typhoons that reached land or traversed the provinces of east China in 31 years (1893–1924)*

	Kwantung	Fukien	Chekiang	Kiangsu	Shantung	Liaotung	Total
April	1	0	0	0	0	0	1
May	5	1	2	0	0	0	8
June	7	1	2	1	0	0	11
July	28	13	7	11	6	7	72
August	26	16	14	22	8	6	92
September	24	15	9	7	2	1	58
October	10	1	1	2	0	0	14
November	2	4	0	0	0	0	6
December	1	0	0	0	0	0	1
Total	104	51	35	43	16	14	263
Average	3.3	1.6	1.1	1.3	0.5	0.4	8.5

of year the great winter anticyclone of Siberia encroaches upon the plains of Mongolia and Manchuria and these provinces as well as those of Chili, Shansi, Shensi and Kansu receive very little precipitation, most if not all of which is in the form of snow. Two areas in south China, the eastern one in Chekiang and northern in Fukien receive as much as 200 mm. (7.87 inches) the second area receiving an equal amount is found immediately to the west of the one just described and is in the provinces of Kiangsi and Hunan.

In spring the rainfall of north China increases quite rapidly, in fact it is more than double that of winter and this is also true of south China as well. In the south of

Chart XIV. A. J. H. Mean Annual Rainfall for China (mm.)



China there is a single area of as much as 600 mm. (23.62 inches) centered in and around the Province of Kiangsi whence the amounts shade off to 300 mm. on the coast and also in the Yangste Valley below Chunking.

In summer the maximum precipitation is reached in all China. An area of 500 mm. (19.68 inches) appears just west of the Gulf of Pechili and near to Peking. Three other areas of large precipitation appear in the south; the first is in the lower Yangste Valley, the second in Kwantung and on the coast from Canton to Pakhoi, while the third is just west of Yunnan in the Province of the same name. In autumn the rainfall decreases; north of the Yangste Valley it generally amounts to less than 200 mm. and in the far north many stations have less than 100 mm.

In the south the maximum of autumn reaches 400 mm. (15.75 inches) in parts of Chekiang and Kiangsi and also along the coast from Hong Kong to the Island of Hainan and finally there is a region of 300 mm. (11.81 inches) in western Yunnan.

Extremes of rainfall.—The absolute maximum yearly rainfall at any one station in China during the observational period was 3,962.9 mm. (156.02 inches) in 1923 at Pakhoi, on the Kwantung coast in north latitude 21 : 29. The author remarks that this is not extraordinary for the latitude of that station, and that the total as given for that station may easily be surpassed in northeast Formosa. At Kuling, central China, in north latitude 29 : 30 in 1911, a total of 3,381.7 mm. (120.61 inches) was recorded, of which 700.3 mm. (27.57 inches) fell in August and 628.4 mm. (24.741 inches) in September. Interior stations of the central plain of China have recorded as much as 1,788 mm. (70.39 inches) (Wuhu, 1911), and on the plains north of Peking a fall of 1,052.2 mm. (41.42 inches) in 1924 is of record. The minimum annual precipitation, as well as the maximum, is given in Table 3 for as many of the stations as have sufficiently long records to yield dependable data.

The maximum 24-hour rainfalls reach a total of as much as 540 mm. (21.26 inches) on the Kwantung coast and as much as 707 mm. (27.83 inches) was recorded on Victoria Peak, Hong Kong, on May 5, 1889, under the influence of a typhoon. In the interior remote from the coast the maximum 24-hour amounts are in the neighborhood of 300 mm. (11.81 inches).

These amounts agree fairly well with maximum 24-hour rainfalls in the United States.

RAINFALL VARIABILITY

The ratio of the greatest annual rainfall to the least annual gives a measure of the rain variability in China. That ratio is given in the final column on the right side of Table No. 1. In general it is somewhat larger in China than in the United States, the country with which this reviewer is best acquainted. Two cases were found in which the record for the year of minimum precipitation is evidently faulty, the first being for North Saddle, year 1887, with a total of but 86 mm. (3.38 inches) whereas the maximum for the same station was 1,566.3 mm. (61.66 inches) and the mean is 829 mm. (32.67 inches). The second case is that of Lungchow for 1902 with a total of 197.3 mm. (7.76 inches). The maximum for this station was 1,792.0 mm. (70.55 inches) and the mean is 1,269.3 mm. (50.30 inches). In Table 1 the reviewer has used the next higher minimum value.

In a country so large as China it is not to be expected that years of great deficiencies in rainfall will occur rather generally over an extended area but rather that the stations having great deficiencies of rainfall will have a local distribution being confined to parts of provinces and this expectation is fully confirmed by the published records in Father Gherzi's contribution. Dry years in China seem to occur in groups rather than in any one individual year, thus 1887, 1888, and 1889 were dry years in Shantung, 1894 and 1895 were dry along the coast of Kwantung and Kiangsu. There was also a series of dry years 1899–1903 with the greatest drought in 1902 in Hupeh, Szechewan Chihli, and Kwangsi. The year 1910 was a dry year in China as well as in the United States.

Mean annual distribution.—Figure 2 is a reproduction of Father Gherzi's map of annual precipitation. In commenting on this map he attributes the area of relatively large rainfall near Peking to orographic influences.

In south China, however, it is different; there are shown on the map by shading three areas of great rainfall, near the coast, one in Chekiang to the north of Fukien and Kiangsi, the other northeast of Kwantung and southeast of Kiangsi and the third around Pakhoi. The orographic influence does not seem to dominate in these cases, seeing that Kweichow where there are great mountain masses the quantity of rain received is well below that of the three zones above-mentioned. Since, however, rainfall stations in Kweichow are few the belief is expressed by the author that the mean annual isohyet of 1,500 mm. (59.05 inches) is reached in that Province.

The large rainfall in the three regions mentioned is clearly due to the effect of typhoons.

The cross-hatching in Figure 2 is not drawn strictly to scale since the idea of the author was simply to emphasize the fact that certain regions had a maximum of precipitation as compared with immediately adjacent areas.

The rainfall régime of a large part of China resembles rather closely that of the Great Plains States of North America, although the yearly maximum in the latter is reached a little earlier in the year than in China and of course, the typhoon effect whereby the yearly maximum in parts of China is reached in July, is absent from North America.

The wet years in some parts of China were 1889, 1903, 1905–06, 1911, 1914–15, and 1920–1924 but in some of these years there were places where the rainfall was deficient.

In other words the rainfall distribution in China does not differ materially from that in other parts of the world.

Failure of the summer rains and an absence of typhoons are the main causes of drought which is naturally more acute in the northern provinces than in the southern because of the smaller average precipitation in those provinces.

Lack of space prevents us from touching upon other interesting features in Father Gherzi's report.

I have grouped in Table 3 the records of the fundamental stations and have added a small number of the most valuable of the secondary stations as published in the original so as to give in a single table the records of the most representative rainfall stations in China. The table follows on next page.

TABLE 3.—*Monthly and annual mean precipitation, greatest and least annual and their ratio*

[The annual values have been rounded off to whole millimeters; monthly values in millimeters and tenths, Chinese stations]

Province and station	From	To	North latitude	East longitude	Elevation	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual			Ratio
																		Mean	Max.	Min.	
			° ′	° ′	m.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	
Manchuria:																					
Antung	1907	1924	40 06	124 21	9	9.9	11.2	24.3	37.4	90.1	100.4	272.3	214.5	130.0	64.3	41.2	5.7	1,001	1,636	504	3.25
Hunchun	1914	1924	42 53	131 18	104	1.6	1.3	11.1	30.4	78.7	73.7	92.4	111.9	108.0	39.2	24.0	1.9	574	796	374	2.13
Kungchuling	1915	1924	43 31	124 48	203	5.3	3.3	10.7	17.5	53.1	87.5	172.8	144.4	67.5	38.7	13.4	3.8	618	841	392	2.15
Mukden	1906	1924	41 48	123 23	44	4.2	6.4	19.3	27.6	57.1	85.7	159.1	156.0	83.7	40.3	26.7	6.1	672	1,065	341	3.12
Newchwang	1902	1924	40 41	122 16	3	5.5	4.9	26.2	26.8	53.2	64.1	157.5	156.0	74.8	39.2	24.5	6.3	639	947	396	2.40
Harbin [1]	1898	1920	45 46	126 50	147	4.1	5.9	8.4	23.5	40.7	104.8	147.6	104.0	53.9	30.0	8.4	5.3	537	745	376	1.98
Chihli:																					
Chinwangtao	1908	1924	39 55	119 38	3	2.9	3.0	15.8	15.8	61.3	71.3	193.1	187.7	78.7	26.7	13.6	2.1	673	987	369	2.68
Peking [2]	1875	1908	39 57	116 28	38	5.5	3.7	9.2	21.7	21.3	73.2	263.8	151.6	60.1	19.3	7.2	0.8	637	1,084	351	3.09
Shuangyin	1909	1924	39 00	117 37	4	4.7	2.7	9.2	11.4	28.4	74.2	164.8	151.3	42.2	16.6	11.0	1.9	518	905	238	3.80
Tangku	1891	1925	39 09	117 11	5	3.5	2.4	10.3	17.0	27.3	64.2	173.9	133.3	48.4	16.0	9.8	3.1	509	796	254	3.13
Tientsin [1]	1908	1925 [3]	36 19	115 12	(?)	10.8	9.1	13.3	17.2	20.0	64.8	138.0	143.0	88.0	16.1	12.4	3.5	536	867	251	3.45
Tamingfu [1]	1919	1925	39 08	116 59	(?)	3.2	4.0	9.2	12.2	27.8	72.1	188.8	136.9	32.8	15.5	6.0	6.5	515	874	432	2.02
Shansi:																					
Sinchow [1]	1919	1925	38 28	112 45	(?)	1.6	2.1	11.5	18.5	28.2	45.2	155.1	108.4	35.1	11.9	3.7	1.2	422	501	365	1.37
Tatungfu [1]	1919	1925	40 07	113 13	(?)	0.9	4.9	7.3	16.5	35.9	46.3	111.3	92.3	30.7	22.5	2.3	0.2	371			
Tienchin [1]	1921	1924 [3]	40 30	113 59	(?)	1.2	0.0	8.2	7.7	28.4	41.5	111.3	109.7	30.2	23.3	1.1	0.7	363			
Luanfu [1]	1919	1925	36 05	113 03	(?)	6.9	8.0	11.7	29.9	35.8	61.0	188.8	81.6	45.2	19.2	2.7	6.9	497	675		
Shensi: Tungyuenfong [1]	1921	1924	34 30	109 04	365	3.0	0.5	7.4	33.6	59.3	47.2	91.3	133.9	50.4	22.0	6.0	6.3	460			
Shantung:																					
Chefoo	1886	1924	37 33	121 22	3	12.9	10.5	16.5	25.8	33.4	60.4	169.7	155.8	64.1	25.0	28.6	17.1	620	976	360	2.71
Howki	1880	1924	38 04	120 39	90	3.6	3.6	9.4	19.4	33.2	53.0	142.5	99.3	55.6	21.2	17.7	4.0	462	1,141	266	4.29
Northeast Promontory	1886	1924	37 24	121 42	54	8.6	6.7	14.5	32.7	33.8	67.2	137.8	126.9	69.5	27.8	26.6	14.6	567	900	219	4.11
Southeast Promontory	1886	1924	36 54	122 32	12	9.9	11.0	19.8	39.8	44.9	77.9	164.2	151.9	81.2	31.6	33.6	17.0	683	1,135	360	3.15
Tsingtao	1898	1924	36 04	120 19	77	10.6	9.8	20.2	38.0	41.1	85.0	155.5	147.0	83.5	33.2	20.6	16.0	660	1,273	353	3.60
Tsinanfu [1]	1916	1925	36 44	117 08	(?)	6.7	10.3	11.1	18.2	42.1	84.1	205.4	156.1	68.9	15.0	8.2	5.0	631	1,021	530	1.93
Szechewan:																					
Chungking	1891	1924	29 34	106 31	230	16.5	20.0	35.2	102.0	140.6	181.4	142.7	130.5	147.3	114.8	49.6	22.0	1,108	1,519	848	1.80
Tengyuech	1911	1924	24 45	98 14	1,633	11.1	28.7	48.4	69.7	122.2	247.8	294.1	282.8	159.8	158.6	36.3	19.2	1,479	1,793	1,154	1.55
Chengtu [1]	1907	1925	30 38	104 02	(?)	8.4	10.5	12.2	48.0	56.1	113.0	203.2	252.6	108.8	47.8	14.9	4.5	880	1,002	588	1.70
Honan:																					
Chengtefu [1]	1922	1925	36 04	114 20	(?)	5.5	7.9	10.2	25.8	29.1	41.7	193.3	132.7	44.1	14.7	1.5	1.9	508	924		
Weihweifu [1]	1919	1925	35 22	114 03	(?)	7.1	6.2	8.7	33.0	33.2	51.0	216.7	99.5	40.3	12.5	1.8	1.5	512	647		
Kaifeng [1]	1923	1926	34 43	114 24	(?)	7.0	13.4	16.2	19.1	27.2	53.4	270.5	118.7	66.1	25.8	5.8	8.0	631	881		
Fukow [1]	1919	1925	34 09	114 30	(?)	14.2	17.1	11.9	32.0	38.4	90.4	225.1	117.4	62.0	20.9	16.4	12.4	678			
Shanchow [1]	1918	1925	34 50	111 06	(?)	5.2	2.9	14.4	20.5	56.9	57.4	104.8	101.3	67.4	27.7	4.7	3.6	467	674	197	3.42
Hupeh:																					
Hankow	1880	1924	30 35	114 17	36	44.7	49.2	95.7	152.0	166.0	242.8	181.2	97.3	72.3	82.3	48.0	27.0	1,258	2,106	576	3.66
Ichang	1882	1924	30 42	111 16	518	19.5	29.1	53.6	100.6	122.6	154.8	210.8	169.5	100.4	84.0	35.8	14.1	1,095	1,493	644	2.32
Shasi [1]	1906	1920	30 18	112 15	51	31.4	42.1	86.7	127.8	133.9	176.0	203.4	161.6	86.9	94.7	64.2	19.1	1,228	1,610	829	1.94
Anhwei:																					
Tungcheng [1]	1912	1922	31 04	117 02	(?)	22.5	54.8	81.9	177.3	142.3	289.0	179.6	163.7	113.7	112.1	98.0	23.5	1,458	2,348	1,027	2.29
Nansuchow [1]	1917	[3]1923	33 41	117 02	(?)	10.7	9.2	25.7	20.9	15.7	48.1	118.5	121.0	69.0	26.5	24.4	16.2	500	718	144	4.99
Hwokiu [1]	1906	1911	32 22	116 15	(?)	52.6	19.4	81.5	59.0	51.1	260.0	189.3	144.9	82.4	60.8	49.3	13.6	1,064	1,503	878	1.71
Wuhu	1880	1924	31 20	118 21	15	54.4	58.0	104.1	130.1	125.7	211.7	164.2	121.1	83.4	75.8	56.1	34.0	1,219	1,788	580	3.08
Kiangsu:																					
Chinkiang	1886	1924	32 13	119 25	12	40.4	44.2	74.7	92.0	90.7	177.7	185.9	122.3	97.5	47.8	41.2	25.2	1,040	1,583	552	2.87
Gutzlaff	1886	1924	30 49	122 10	75	47.0	60.0	94.1	96.9	84.1	141.2	90.4	66.9	100.3	73.7	46.5	35.8	937	1,337	565	2.37
Lukiapang	1908	1924	31 19	121 02	5	37.4	55.9	84.6	91.4	80.3	229.2	145.0	112.5	117.0	66.5	54.8	39.7	1,114	1,455	878	1.66
Nanking	1905	1924	32 05	118 49	16	41.1	50.2	75.1	101.0	81.9	182.7	207.0	115.7	93.6	49.7	41.2	29.8	1,069	1,621	576	2.81
Nantung	1917	1924	31 57	120 55	110	22.5	42.3	66.1	70.8	67.8	176.9	174.4	156.1	134.6	21.9	36.1	32.0	1,002	1,391	631	2.21
North Saddle	1886	1924	30 52	122 40	72	34.3	47.9	74.0	84.3	86.4	134.8	75.6	64.0	82.9	66.7	45.1	33.0	829	1,566	520	3.01
Shaweishan	1886	1924	31 25	122 14	53	42.3	51.5	80.1	85.6	85.8	151.1	102.3	105.7	112.4	74.0	47.1	28.9	967	1,335	624	2.14
Steep Island	1886	1924	30 13	122 35	63	43.5	54.2	89.2	98.0	96.6	155.4	66.3	55.3	78.3	69.4	41.4	27.8	875	1,338	633	2.11
Woosung	1904	1924	31 23	121 29	3	35.0	49.8	72.9	79.2	76.6	187.0	134.8	111.8	111.7	60.6	51.9	31.4	1,006	1,298	781	1.66
Zi-ka-wei	1873	1924	31 12	121 26	7	49.8	59.6	87.4	93.9	92.0	187.6	149.7	144.1	120.3	79.2	51.0	33.3	1,148	1,588	700	2.24
Chekiang:																					
Ningpo	1886	1924	29 57	121 45	10	68.3	88.1	109.9	118.2	112.0	190.1	126.0	176.5	177.4	109.1	62.9	47.9	1,386	2,135	912	2.34
Peiyushan	1904	1924	28 53	122 16	82	42.4	90.2	106.6	113.2	122.1	157.5	67.3	109.2	171.7	73.5	53.3	55.8	1,163	1,669	835	2.00
Wenchow	1883	1924	28 01	120 40	3	46.6	93.8	122.7	153.0	179.9	264.8	198.5	234.8	204.2	93.5	57.2	40.4	1,689	2,919	1,136	2.57
Hangchow [1]	1904	1919	30 11	120 12	10	61.7	84.8	136.6	146.3	110.5	248.7	151.6	176.0	134.6	107.3	82.2	60.3	1,501	1,836	1,212	1.51
Kweichow: Kweiyang [1]	1923	1926	26 18	106 40	1,075	29.5	22.5	27.8	85.1	165.7	164.5	247.9	87.6	164.5	113.4	45.1	15.4	1,169			
Hunan:																					
Changsha	1909	1924	28 12	112 47	60	45.0	96.2	145.8	154.8	198.8	221.8	121.1	131.7	85.1	89.2	78.9	44.0	1,412	2,019	939	2.15
Yochow	1909	1924	29 24	113 10	(?)	32.4	73.1	143.2	153.3	152.2	223.8	115.4	115.2	73.7	96.6	109.5	34.1	1,322	1,691	912	1.85
Kiangsi:																					
Kiukiang	1885	1924	29 45	116 08	20	62.5	82.7	150.9	181.2	173.9	242.7	143.4	131.4	88.6	97.0	68.1	43.3	1,466	2,064	765	2.70
Kuling [1]	1909	1912	29 30	116 04	1,070	51.6	69.3	173.8	164.7	195.8	361.1	256.2	320.7	190.3	122.4	108.3	58.6	2,073	3,382	1,133	2.98
Fukien:																					
Amoy	1880	1924	24 27	118 05	4	32.4	77.3	89.0	125.7	157.6	177.4	133.2	167.7	109.5	49.3	31.6	31.8	1,182	1,638	654	2.50
Chapel Island	1880	1924	24 10	118 30	55	30.6	60.4	86.6	114.5	134.6	145.0	106.1	115.9	95.1	49.7	32.3	29.4	1,000	1,509	517	3.11
Foochow	1880	1924	25 59	119 27	20	47.0	96.3	115.0	121.8	149.7	208.1	161.0	182.0	214.3	50.9	41.4	47.2	1,435	2,730	896	3.05
Middle Dog	1892	1924	25 58	119 59	59	44.1	95.8	117.7	127.8	157.3	190.6	114.8	91.1	149.8	71.6	46.1	39.5	1,246	1,883	725	2.60
Ocksen	1886	1924	25 00	119 27	63	29.4	58.1	88.7	97.5	138.2	168.5	78.5	91.0	75.9	32.8	21.3	24.5	904	1,438	432	3.33
Santuao	1917	1924	26 45	119 45	4	44.2	91.6	125.5	146.5	208.2	281.3	170.4	194.6	225.1	91.0	43.9	59.9	1,688	2,219	1,067	2.08
Tungyung	1905	1924	26 22	120 30	111	24.9	76.6	82.4	83.9	135.6	119.5	61.3	69.0	91.2	4.73	25.9	21.6	839	1,605	406	3.95
Turnabout	1885	1924	25 26	119 56	65	38.9	78.1	105.0	117.7	160.4	185.2	86.5	106.7	100.7	54.7	40.5	42.6	1,117	1,830	572	3.20
Yunnan:																					
Mengtsz [1]	1906	[3]1925	23 23	103 24	1,305	9.0	13.7	26.6	42.5	103.1	129.1	179.2	191.2	105.9	54.6	56.4	13.5	925	1,160	666	1.74
Yunnanfu [1]	1902	[3]1925	25 02	102 41	1,893	13.4	12.9	13.7	18.3	93.6	154.8	238.8	206.6	136.3	92.3	44.2	15.4	1,040	1,451	844	1.72
Kwangsi:																					
Kiungchow	1912	1924	20 01	110 16	10	25.2	26.0	72.2	94.1	174.6	209.8	247.2	207.2	258.2	190.6	83.1	59.0	1,647	1,829	1,500	1.22
Lungchow	1896	1924	22 22	106 45	(?)	19.2	27.0	47.7	84.6	171.4	216.0	222.7	231.4	133.3	53.6	40.8	21.6	1,269	1,792	551	3.25
Wuchow	1898	1924	23 29	111 20	2	30.3	49.0	86.7	171.0	202.6	196.3	166.9	178.8	98.9	35.9	43.9	38.2	1,298	1,734	925	1.87
Kweilin [1]	1916	1926	25 19	110 20	(4)	37.6	96.8	128.7	242.3	357.6	391.0	180.6	186.5	88.3	84.3	51.5	40.8	1,986	2,469	1,399	1.76
Kweishien [1]	1918	1926	25 18	109 34	(4)	34.9	87.6	84.1	136.8	280.5	301.7	228.0	257.2	124.8	45.6	48.5	36.9	1,667	1,952	1,202	1.62
Nanning [1]	1921	1926	22 40	108 03	(4)	38.4	61.5	58.9	102.2	149.6	298.3	263.7	266.7	166.3	96.9	22.9	30.0	1,564	1,971	1,177	1.67
Nanyung [1]	1919	1926	25 16	114 04	(4)	53.8	125.7	152.8	229.4	245.5	271.3	99.7	204.4	83.6	80.6	34.3	34.4	1,616	1,882	1,168	1.61
Poseh [1]	1916	1926	23 52	105 57	(4)	19.3	30.3	36.2	74.7	178.7	216.4	270.8	225.4	132.4	44.2	41.5	16.1	1,286	1,660	949	1.75
Sanli [1]	1918	1926	23 31	109 38	(4)	61.3	88.6	56.1	102.3	221.5	282.9	182.3	228.5	124.4	51.8	84.2	48.5	1,532			
Shanglin [1]	1918	[3]1926	23 28	108 24	(4)	58.0	129.5	99.8	144.0	244.2	336.6	306.0	331.3	168.4	56.9	61.5	55.2	1,986	2,718	1,480	1.84
Shekiung [1]	1920	1926	23 05	113 59	(4)	41.1	108.7	109.7	179.5	256.6	252.1	272.0	302.4	139.8	39.5	59.5	14.8	1,776			

[1] Secondary station. [2] Station of Russian Legation. [3] Broken record. [4] Not known accurately.

TABLE 3.—*Monthly and annual mean precipitation, greatest and least annual and their ratio*—Continued

[The annual values have been rounded off to whole millimeters; monthly values in millimeters and tenths, Chinese stations]

Province and station	From	To	North latitude	East longitude	Elevation	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual			Ratio
																		Mean	Max.	Min.	
			° ′	° ′	m.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	
Kwangsi—Continued.																					
Silung [1]	1916	1926	24 27	105 30	(4)	13.9	23.0	40.3	58.8	170.5	286.8	264.0	290.8	156.7	70.4	48.3	21.7	1,445	-------	-------	-------
Souyen [1]	1916	1926	24 19	110 18	(4)	34.7	68.6	94.1	145.9	234.5	250.2	156.4	199.7	84.8	40.5	49.5	36.1	1,395	-------	-------	-------
Sunchow [1]	1918	1926	23 17	109 59	(4)	65.9	122.8	97.9	203.9	323.5	397.2	243.6	259.8	132.2	60.0	80.0	65.5	2,052	2,249	1,641	1.31
Szengsnfu [1]	1918	1926	23 22	108 02	(4)	51.5	87.0	67.0	135.4	188.5	294.0	287.2	328.9	154.4	49.0	59.3	44.0	1,746	-------	-------	-------
Yungfu [1]	-------	-------	25 01	109 59	(4)	50.8	126.6	125.0	215.0	416.3	456.5	203.6	235.3	100.7	94.3	62.9	47.3	2,134	-------	-------	-------
Kwantung:																					
Breaker Point	1892	1924	22 56	116 30	17	27.9	47.2	57.1	109.9	201.0	286.8	210.7	270.9	169.2	99.4	37.4	31.5	1,549	2,190	715	3.06
Canton	1907	1924	23 07	113 16	15	49.6	75.0	75.7	148.5	254.2	264.7	271.3	282.5	134.6	63.2	44.4	35.5	1,699	2,796	1,102	2.54
Chilang Point	1911	1924	22 40	115 40	28	21.8	58.2	61.4	94.6	181.3	258.4	232.4	240.9	140.5	48.0	34.5	29.1	1,401	1,985	989	2.01
Lamocks	1892	1924	23 16	117 17	58	28.1	36.9	55.6	99.3	124.7	177.7	166.3	164.8	139.3	85.3	26.7	23.4	1,128	1,834	545	3.37
Macao	1910	1924	22 12	113 32	20(?)	22.1	51.0	64.7	121.8	307.7	338.6	235.7	253.0	172.9	112.6	54.7	26.4	1,761	2,375	1,305	1.82
Pakhoi	1885	1924	21 29	109 07	5	32.0	33.1	76.0	107.2	171.1	292.8	503.0	506.6	272.5	81.2	45.4	48.4	2,169	3,962	1,389	2.85
Hong Kong	1884	1924	22 18	114 10	32	32.7	44.5	68.0	134.9	304.2	402.5	356.0	371.9	247.0	130.1	43.2	27.3	2,162	3,041	1,164	2.67
Samshui	1900	1924	23 06	112 53	10	41.8	65.5	112.3	184.3	305.0	267.7	243.5	260.7	143.4	69.5	47.6	45.9	1,787	2,401	1,044	2.30
Swatow	1880	1924	23 23	116 40	4	35.3	62.5	79.9	143.5	229.5	266.6	197.8	212.2	138.5	73.0	39.4	38.1	1,516	2,512	670	3.75
Kwangchowwan [1]	1913	1925	21 05	108 10	14	15.7	28.6	42.8	76.6	171.2	214.5	220.4	310.5	185.5	59.7	52.7	28.7	1,407	1,715	1,133	1.51
Liuchow [1]	1921	1926	24 53	112 57	(4)	40.1	105.1	131.4	195.7	309.6	250.8	148.3	129.3	58.4	86.9	42.8	27.1	1,526	-------	-------	-------
Nanyung [1]	1919	1926	25 16	114 04	(4)	53.8	125.7	152.8	229.4	245.5	271.3	99.7	204.4	83.6	80.6	34.3	34.4	1,616	-------	-------	-------
Shekiung [1]	1920	1926	23 05	113 59	(4)	41.1	108.7	109.7	179.5	256.6	252.1	272.0	302.4	139.8	39.5	59.5	14.8	1,776	-------	-------	-------
Shiuchow [1]	1919	1926	24 55	113 08	(4)	38.1	119.7	123.7	202.3	271.0	267.7	84.1	170.5	73.8	62.0	23.8	33.5	1,470	-------	-------	-------
Yintuk [1]	1919	1926	24 10	113 19	(4)	47.8	120.1	133.5	278.3	314.5	340.6	148.7	248.2	92.8	60.9	30.0	27.9	1,843	2,553	1,482	1.72
Hainan (Island):																					
Kiungchow	1912	1924	20 01	110 16	10	25.2	26.0	72.2	94.1	174.6	209.8	247.2	207.2	258.2	190.6	83.1	59.0	1,647	1,829	1,500	1.22
Lamko	1912	1924	20 00	109 42	15	16.1	17.7	39.1	55.5	83.5	129.1	200.8	211.3	194.3	125.7	50.0	27.2	1,150	1,518	707	2.15

[1] Seconday station.

[4] Not known accurately.

RAPID DECREASE IN BAROMETRIC PRESSURE NORTHWEST OF STORM TRACK ON NOVEMBER 17, 1928

By W. S. BELDEN

[Weather Bureau, St. Joseph, Mo.]

A rapid decrease in barometric pressure occurred in southeastern Kansas, northwestern Missouri, and south-central Iowa on the morning of November 17, 1928, in connection with the northeastward movement of a cyclonic area that was central near Columbia, Mo., at 7 a. m., ninetieth meridian time, on that date.

The fall in pressure at St. Joseph, Mo., was 0.25 inch in 40 minutes, from 4:50 a. m. to 5:30 a. m., as shown in Figure 1. Similar though slightly less pronounced falls were registered at Wichita and Iola, Kans., Kansas City, Mo., and Des Moines, Iowa. The time of the earliest abrupt fall was 1:30 a. m. at Wichita. Then followed in order rapid falls at stations to the northeastward, Des Moines being reached at 8:30 a. m.

Although St. Joseph was approximately 150 miles northwest of the storm track, its lowest pressure, reduced to sea level, was lower than any other sea-level pressure reported in the cyclonic area west of the Mississippi River. See accompanying table of data.

In or near and to the south of the storm track recorded pressure falls were generally gradual. The greatest in two hours ranged from 0.06 to 0.13 inch, except at Columbia and Springfield, Mo., where the sharpest decreases, amounting to 0.10 inch in each case, came within about one hour, and at the apparent time of the nearest approach of the storm center. In Nebraska and western and north-central Kansas pressure changes attending the passage of the storm were not unusual.

The decided pressure decreases were each accompanied by northerly surface winds, the highest velocity being 32 miles an hour from the northeast at Wichita.

Excessive rainfall, mostly in the northeast quadrant of the cyclone, occurred over a belt approximately 100 miles wide extending from northcentral Oklahoma northeastward to southeastern Iowa. Thunderstorms were general in Oklahoma, Kansas, Missouri, and Iowa on the 16th but the only stations reporting thunderstorms on the 17th were Wichita and Kansas City.

Temperatures were much above normal in Missouri and adjacent States on the 16th, and in the central, southern, and eastern portions of Missouri on the morning of the 17th, when the temperature ranged from 40° at St. Joseph to 60° at St. Louis.

The lowest observed sea level pressure readings appear on Figure 2. Isobars show that over most of Missouri and southeastern Iowa the minimum pressure was less than 29.60 inches, with three centers of low pressure.

Hour lines indicating the progressive movement of the abrupt falls in pressure appear on Figure 3. The lines for 9 a. m., 10 a. m., and 11 a. m. have been drawn not for the lowest readings, but for slight sharp falls, which seem to be directly associated with the more abrupt falls. The lowest pressure readings at Hannibal, Keokuk, Davenport, and Dubuque were in each case registered later than the slight sharp falls. At Oklahoma City the lowest barometer reading occurred at 5 p. m. November 16, the time of the nearest approach of the center of the storm area, but after the barometer had risen gradually for more than four hours, a fall of 0.08 inch was registered within 30 minutes ending at 10:10 p. m. This slight sharp fall also seems to be associated with the more abrupt falls, thus giving a basis for beginning the hour lines at 10 p. m. November 16.

A secondary atmospheric whirl of much intensity but somewhat limited diameter appears to have developed aloft over central Oklahoma about 10 p. m. November 16.

The course of the secondary disturbance was to the northeastward, as indicated by arrows that cross the hour lines in Figure 3. It passed near or over St. Joseph, causing a remarkably rapid fall in pressure, and spent nearly all of its energy before reaching extreme east-central Iowa. Its rate of movement seems to have been greater than the rate of advance of the primary storm area.

It should be noted that (1) the lowest pressure at Kansas City was 0.09 inch higher than the lowest pressure at St. Joseph, thus giving evidence of a ridge of pressure between the primary and secondary depressions; (2) the direction of surface winds was not materially affected by the passage of the secondary whirl; (3) the velocity of surface winds was not as great as that which usually attends such wide fluctuations in pressure; and (4) assuming that the atmospheric whirl existed aloft, as outlined, it would not have been subject to the retarding influence, experienced by the primary cyclonic area, resulting from friction with the ground.

Pressure and wind conditions on November 16–17, 1928

Stations	Lowest barometer (sea level)	Time	Greatest fall in pressure within 2 hours	Maximum wind velocity, direction, and time
Nov. 16				
Oklahoma City, Okla.	29.65	5:00 p. m.	0.08	20, N., 9:34 p. m.
Fort Smith, Ark.	29.72	10:00 p. m.	.06	30, SW., 10:04 p. m.
Nov. 17				
Wichita, Kans.	29.64	1:30 a. m.	.20	32, NE., 1:36 a. m.
Iola, Kans.	29.58	2:00 a. m.	.17	19, N., 7:24 p. m. (16th).
Concordia, Kans.	29.92	7:10 a. m.	.07	24, NW., 9:43 a. m.
Springfield, Mo.	29.58	5:00 a. m.	.13	28, W., 11:31 a. m.
Columbia, Mo.	29.54	7:00 a. m.	.10	23, SW., 12:35 p. m.
Kansas City, Mo.	29.61	5:00 a. m.	.17	30, NE., 5:30 a. m.
St. Joseph, Mo.	29.52	5:30 a. m.	.27	25, NE., 5:22 a. m.
Omaha, Nebr.	29.85	7:00 a. m.	.09	28, N., 6:45 a. m.
Des Moines, Iowa.	29.62	8:30 a. m.	.21	22, N., 8:36 a. m.
Charles City, Iowa.	29.77	12:00 noon	.12	17, NE., 11:35 a. m.
La Crosse, Wis.	29.76	12:30 p. m.	.10	11, N., 10:34 a. m.
Davenport, Iowa.	29.53	1:00 p. m.	.09	
Dubuque, Iowa.	29.60	1:45 p. m.	.13	18, N., 5:12 p. m.
Keokuk, Iowa.	29.57	12:00 noon	.06	18, NE., 3:28 p. m.
Hannibal, Mo.	29.55	12:30 p. m.	.06	28, SW., 2:16 p. m.
St. Louis, Mo.	29.63	10:00 a. m.	.07	36, W., 4:23 p. m.

NOTE

A somewhat similar phenomenon occurred on February 20, 1927, between 4 and 5 a. m. at the New York station. Mr. Gerald J. O'Connor brought this matter to the attention of the central office and remarked that he had noted a similar occurrence on May 12, 1923. In the February, 1927, case the temperature was steady at about 24°, with sleet and rain and fresh easterly winds. The barograph trace showed a sudden fall of 0.10 inch and a rise of 0.09 inch, both within the hour, 4 to 5 a. m. Similar but less accentuated conditions were noted as follows: Atlantic City, 3 a. m.; Philadelphia, 3 a. m.; Trenton, 3 to 4 a. m.; Sandy Hook, 4:15 a. m.; New York. 4:15 a. m.; Block Island, 11:15 a. m.; Providence, 11:30 a. m. But the traces at Washington, Baltimore, Harrisburg, Reading, Scranton, and New Haven showed nothing of this kind.

With steady temperatures and persistent northeast winds, without any shift at the surface, we naturally have recourse to the conditions in the free air. From the fact that sleet was falling it may be inferred that a warm current existed aloft, probably from the southwest or south.

A high-pressure area of 30.9 inches was central over the Gulf of St. Lawrence, with a low 29.75 inches over extreme eastern Tennessee, and another of 29.75 inches on the Virginia coast. From the latter center a line of discontinuity extended approximately eastward off the coast. From this line, a surface of discontinuity sloped northward in the free air, as indicated by the fact that it was sleeting at New York. No doubt along this surface there was considerable mixing due to turbulence and it seems probable to Professor Humphreys and myself that a small disturbance passed over New York City in the free air in this turbulent layer. If we take the distance from Atlantic City to New York as 100 miles and the time interval as 1 hour and 45 minutes, the rate of travel of the disturbance was in the neighborhood of 55 to 60 miles per hour.

A phenomenon of this character has also been noted by Sir Napier Shaw in his Forecasting the Weather, first edition, pages 253, 254.—*R. H. Weightman.*

A DENSE SMOKE CLOUD ON JANUARY 3, 1929, AT WASHINGTON, D. C.

By IRVING F. HAND

[Weather Bureau, Washington, January 9, 1929]

Cold mornings with little or no wind and consequent piling up of city smoke have been productive of many noteworthy smoke clouds which have passed over the Solar Radiation Observatory of the Weather Bureau, located on the campus of the American University in the northwest suburbs of Washington,[1] but none heretofore has yielded as many dust particles as the cloud which passed over this section of the city about 9:30 a. m., January 3, 1929. The American University is located about 2 miles from Georgetown, an industrial center of Washington, 4 miles northwest of the White House, and 5 miles from all important railroads.

Table 1 shows in condensed form the number of dust particles collected by both the Owens[2] and Hill[3] dust counters, together with certain meteorological data. Not only was the number of these particles the maxima ever obtained in Washington, but their size averaged about 0.0015 mm. in diameter, or about twice the diameter of those usually collected.

TABLE 1.—*Number of dust particles and meteorological data during the passage of a dense smoke cloud over northwest Washington, January 3, 1929*

Time	Number of dust particles		Temperature	Rel. hum.	Vapor pressure	Wind		Visibility	
	Owens counter	Hill counter				Direction	Velocity	West	East
	Per cu. cm.	*Per cu. ft.*	*Per cu. ft.*	*°F.*	*Per cent*	*Inch*			*Miles*	*Miles*
8:00 a. m.	638	18,066,246	18,788	24	64	0.063	0	0	12	1
9:30 a. m.	12,810	363,637,470	469,700	27	53	.076	S.	2	3	¼
Ratio { 9:30 a. m. / 8:00 a. m. }		20.1	25.0							

[1] Mo. Wea. Rev., 1925, 53: 147–148. Mo. Wea. Rev., Jan., 1926, 54: 19–20.
[2] Mo. Wea. Rev., Mar., 1924, 52: 133–139.
[3] It collects the particles in a measured quantity of air by causing them to impinge upon the object glass of a microscope, the surface of which is covered by a thin coating of white vaseline.

The ratio of the 9:30 a. m. to the 8 a. m. measurements by each instrument indicates a greater increase in

the coarse than in the fine particles, since the microscope used with the Hill instrument magnifies only 80 diameters, which makes visible particles 0.0001 inch, or 0.00254 mm. in diameter, while a microscope magnifying 1,000 diameters is used to count the dust collected by the Owens instrument, which makes visible particles having a diameter somewhat less than the shortest wave length of visible light, or about 0.0002 mm.

The effect of this cloud upon the amount of solar radiation received from the sun at normal incidence is striking. A pyrheliometric measurement at 9:03 a. m. gave an intensity of 0.79 gram-calory per minute per square centimeter of normal surface through an air mass of 4 (solar altitude = 14.3°). The following observation, at 9:26 a. m., and through air mass 3.5 (solar altitude = 16.4°) gave a value of 0.22, or one-fourth of what would have been expected had the sky remained free from smoke.

On Figure 1, curve 1 is a reproduction of the actual trace made by the recording Engelhard microammeter of the amount of radiation received directly from the sun and diffusely from the sky during the morning of January 3, while curve 2 is a copy of a trace made by the same instrument four days later when the early morning and noon intensities approximated those of January 3, but with a smoke-free atmosphere throughout the day. This latter trace fairly well represents the amount of radiation we would have expected during the morning of January 3, had the sky remained uncontaminated by smoke. It will be seen that the loss of solar energy amounts to over 60 per cent at 9:30 a. m., the greater part of which was due to reflection of the radiation back into space from individual particles, although a small proportion was absorbed. The curves do not show, however, the well-known fact that a much larger percentage of short-wave radiation is cut off by a smoke cloud than of the long-wave radiation.

The thickness of the smoke cloud was estimated to be at least 100 feet, and while it might have been slightly less dense near the top than at the bottom, convection had set in strong enough to carry many particles to heights greater than 100 feet. Using the measurements by the Owens dust counter, the number of dust and smoke particles averages $363,637,470 \times 27,878,400 \times 100 = 1,011 \times 10^{15}$ over each square mile of surface area. This number, in connection with the average diameter given above gives 110 cubic feet of suspended matter. As soot piled loosely weighs about 42 pounds per cubic foot, we obtain 4,620 pounds of solid matter in the atmosphere over each square mile covered by this smoke cloud.

The material in this cloud was evidently made up principally of products of combustion or smoke. The odor of sulphur trioxide, SO_3, was very noticeable, and it has been found that the combination of water vapor with this gas forms sulphuric acid, in sufficient quantities to be injurious to metal work and masonry in buildings. In addition there were the usual number of spores, fungi, soil and rock materials, decayed vegetable matter, and other objectionable materials.

A normal adult will inhale about 18 times a minute, and with each breath will draw about 30 cubic inches of air into his lungs, or 540 cubic inches per minute. Therefore, while standing in the smoke cloud of January 3 he would have drawn about 113,000,000 solid particles into his respiratory system during each minute.

Since these particles in connection with moisture are injurious to building material, we would expect them to have a deleterious effect upon lung tissues, and such is undoubtedly the case. That the respiratory system of the human body is able to withstand such contaminating influences without serious results is testimony to its wonderful efficiency.

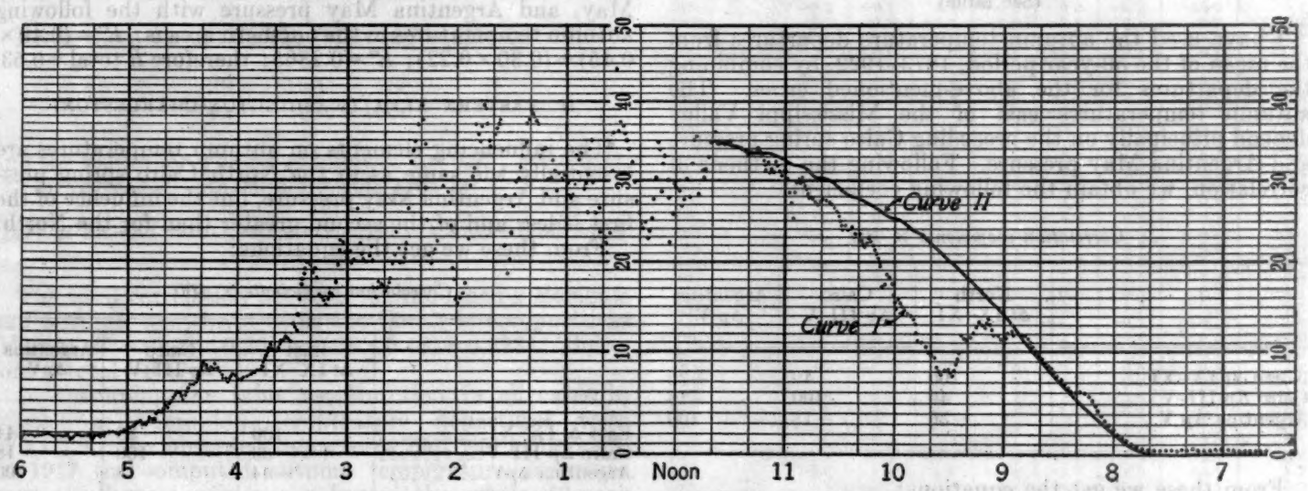


FIGURE 1.—Pyrheliometric record, American University, D. C., January 3, 1929

This smoke cloud was no more dense than is frequently found over the center of large industrial cities. For example, two cities have reported over 500,000 particles per square foot, as measured by the Hill dust counter on several days in December, 1928.

There is some consolation to dwellers in Washington to know that this cloud is twenty-two times as dense as that ordinarily found at the American University during the three winter months, January, February, and March, and eight times as dense as that found over the Weather Bureau in the city proper during the same period.

Continuous or even frequent exposure to smoke clouds of this character has a tendency to weaken the powers of resistance of the respiratory organs to disease. In addition, the ultra-violet rays in sunlight, which are powerful germicides, are completely shut out. This still further increases the opportunity for the spread of disease in cities with smoke-filled atmospheres.

CORRELATION STUDIES: TEMPERATURE IN EASTERN UNITED STATES

By FRED GROISSMAYR, METEOROLOGIST
[Passau, Germany]

Two years ago I published a little study "Correlation Between Argentina Pressure and Temperature in the United States Six Months Later." (Monthly Weather Review, July, 1926, **54**:299).

In course of my further studies on this subject, I found also that Cairo spring pressure III–V (March–May) exerted a large influence upon the autumn temperatures in the eastern United States.

In order to study autumn temperature forecasts in the East, I have selected three territories, namely:

I. Northern area, represented by St. Louis, Cincinnati, and St. Paul.

II. The eastern coast, represented by Charleston, S. C., and Washington, D. C.

III. The Southeast, represented by Mobile, Charleston, and Key West.

I. THE NORTHERN AREA

(See table)

I have used the autumn temperature departures from the mean of the 50-year period, 1873–1922, by combining the departures for the above-mentioned cities. The autumn temperatures east of the Mississippi Valley depend principally on the preceding Cairo spring pressure and Argentina-May pressure. Following the methods of correlation, we obtain the following coefficients:

Correlation coefficients × 100

	North Δt IX–XI	Cairo Δp III–V	Argentina Δp V
North Δt IX–XI	100	49	−30
Cairo Δp III–V	49	100	−18
Argentina Δp V	−30	−18	100

From these we get the equations:

$$49 = 100a - 18c$$
$$-30 = -18a + 100c$$

Solving for a and c results in the following values: $a = 0.45$; $c = -0.22$.

The regression equation:

$$\frac{\Delta t \text{ IX–XI North}}{\delta_n} = \frac{0.45\ \Delta p \text{ III–V } C.}{\delta_c} - \frac{0.22\ \Delta p \text{ V Arg.}}{\delta_a}$$

If we substitute the numerical data for the δ in our formula the regression equation finally becomes:

(I) Δt IX–XI North $= 1.53\ \Delta p$ III–V Cairo $- 0.32\ \Delta p$ V Argentina

where δ_n, δ_c, and δ_a signify, respectively, the standard deviations of the North, Cairo, and Argentina; Δ departures from the mean; t the temperature in °F.; p pressures in mm. Hg; and I, II, III–XI, XII the months, for instance III–V represents March–May.

If we now examine the table of departures we find the following interesting facts of large theoretical and practical importance.

1. In all cases in which the computed autumn temperature departures (from Forumla I) were $\geqq \pm 2°$ F., the observed departures also had the same sign (6 cases = 12 per cent); in the years in which the computations gave only $\geqq \pm 1°$ F. as departure, the observed departures had the same sign in 18 of the 21 cases, or 86 per cent of the time.

2. In all cases where the Cairo spring pressure was $\geqq \pm 0.9$ mm. Hg. (8 cases = 16 per cent), the following autumn in the North had departures with like signs.

3. When Argentina pressure in May was especially low or high ($\geqq \pm 2$ mm. Hg.), the following autumn in the North was warm or cool, respectively, in all of the nine cases.

Therefore Argentina May pressure is inversely related to the autumn temperatures six months later in the United States.

The total correlation between Cairo pressure, March-May, and Argentina May pressure with the following autumn temperatures in the northern area is: $R^2 = (0.49 \times 0.45) + (0.30 \times 0.22)$; $R^2 = 0.2865$; therefore R total $= 0.53$.

II. EASTERN AREA (WASHINGTON-CHARLESTON)

The influencing elements on autumn temperatures are essentially the same as in the North–Cairo spring pressure and Argentina May pressure, but the influence of the first is less and of the second greater than for the North.

From these we get the equations:

Correlation coefficients × 100

	East Δt IX–XI	Cairo Δp III–V	Argentina ΔpV
East Δt IX–XI	100	33	−44
Cairo Δp III–V	33	100	−18
Argentina ΔpV	−44	−18	100

From these we get the equations:

$$33 = 100a - 18c$$
$$-44 = -18a + 100c$$

Solving for a and c results in the following values: $a = 0.26$; $c = -0.39$.

The regression equation:

(II) Δt IX–XI East $= 0.71 \Delta p$ III–V Cairo $- 0.46 \Delta p$V Argentina

The total correlation between Cairo spring pressure and Argentina May pressure with the autumn temperatures for the East (Charleston and Washington) becomes: $R^2 = (0.26 \times 0.33) + (0.39 \times 0.44) = 0.2574$; therefore R total $= 0.51$.

If we examine the table of departures we find the following interesting facts, important for practical use:

1. There are 16 cases in which the computed (Formula II) autumn temperature departures were $\geqq \pm 1°$ F. Among this number are 14, or 87.5 per cent, in which the observed autumn temperatures had the same sign of departure.

2. Of these 16 cases there are 9 for which computation gave $\geqq +1°$ F., and in all of these the autumn was mild.

3. For 1917 the computations gave the largest negative value, and an excessively cold autumn followed, in fact the coldest in the southeastern part of the United States of the whole 50-year period.

III. THE SOUTHERN AREA (MOBILE, CHARLESTON, AND KEY WEST)

In general, the conditions for autumn temperature forecasts are the same as for the East and North, with the difference that Cairo spring pressure is of less influence. We obtain the following coefficients:

Correlation coefficients × 100

	Δt IX–XI South	Δp III Cairo	Δp V Argentina
Δt IX–XI South	100	29	−42
Δp III–V Cairo	29	100	−18
Δp V Argentina	−42	−18	100

From these we obtain the following equations:

$$29 = 100a - 18c$$
$$-42 = -18a + 100c$$

and the values for a and c as follows: $a = 0.22$; $c = -0.38$.

The regression equation for this area is:

(III) Δt IX–XI South $= 0.45\ \Delta p$ III–V Cairo $- 0.33\ \Delta p$ V Argentina

The total correlation between the influencing elements and autumn temperatures in the South is computed as follows: $R^2 = (0.22 \times 0.29) + (0.38 \times 0.42) = 0.2234$; therefore R total $= 0.47$.

In examining the table we find that in all cases in which the computed temperature departures were $\geqq \pm 1°$ F., the observed departures had the same sign. In 1917 the computed autumn temperature departure gave the largest negative value of the whole 50-year period and the autumn was the coldest of the entire series.

Furthermore, we find two years later (in 1919) that the computations gave the largest positive departure, and the autumn in that year was the mildest.

This accordance in all the areas between computations and observations is the best argument for the correctness, usefulness, and importance of my formulas, and leaves no doubt of their practical value.

Departures from the mean

(50 years, 1873–1922)

Year	Autumn temperatures (°F.) eastern United States (Δt IX–XI)						Δp III–V Cairo	Δp V Argentina
	South		East		North			
	Obs.	Comp.	Obs.	Comp.	Obs.	Comp.		
							Mm. Hg.	*Mm. Hg.*
1873	−2.2	−0.1	−2.3	−0.3	−4.6	−1.1	−0.9	−0.8
1874	−0.5	−0.3	−0.2	−0.4	−0.2	0.5	0.7	1.9
1875	−0.8	−0.2	−2.6	−0.4	−3.9	−1.2	−0.9	−0.6
1876	−1.9	−0.2	−2.6	−0.3	−3.2	−1.1	−0.8	−0.5
1877	0.2	−0.4	0.8	−0.5	0.4	−1.2	−0.8	0.1
1878	−0.4	−0.2	0.2	−0.2	0.4	−0.2	0.0	0.5
1879	0.2	−0.2	0.5	−0.3	1.5	−0.3	−0.1	0.6
1880	−0.6	0.0	−1.9	−0.1	−4.0	−0.2	−0.2	−0.2
1881	2.5	0.7	4.8	1.0	2.3	1.1	0.4	−1.5
1882	−0.1	0.5	0.5	0.7	1.7	0.8	0.3	−1.1
1883	1.0	0.0	−1.0	0.1	−0.5	0.2	0.1	0.0
1884	0.7	0.2	2.0	−0.7	2.9	−0.8	−0.3	1.0
1885	−1.1	0.0	−0.8	0.0	−1.7	−0.4	−0.4	−0.7
1886	−0.3	−0.1	0.5	−0.2	0.0	−0.3	−0.2	0.1
1887	−0.7	−0.7	−1.4	−0.9	−2.1	−0.4	0.2	2.3
1888	−0.9	0.4	−1.9	0.6	−2.2	0.1	−0.3	−1.7
1889	−1.1	0.0	−1.5	−0.1	−3.4	−0.4	−0.3	−0.3
1890	0.2	−0.9	0.7	−1.4	−0.8	−2.2	−1.2	1.2
1891	−2.1	−0.1	−1.6	−0.2	−1.0	−0.5	−0.4	−0.3
1892	−1.2	−1.3	−1.8	−1.9	−1.2	−2.1	−0.8	2.8
1893	−0.1	0.0	−0.7	0.0	−0.4	0.4	0.4	0.6
1894	−0.4	−0.2	0.5	−0.3	−0.6	−0.6	−0.4	0.1
1895	−0.2	−0.7	−0.1	−1.0	−1.1	−1.2	−0.5	1.4
1896	1.1	−0.8	0.8	−1.1	−2.9	−1.2	−0.4	1.8
1897	0.8	0.1	0.8	0.5	3.5	0.7	0.3	−0.6
1898	−0.7	0.0	0.3	0.0	−0.6	−0.4	−0.4	−0.7
1899	0.7	0.7	0.4	1.0	3.0	1.0	0.3	−1.8
1900	1.6	0.1	3.2	0.2	3.4	0.3	0.2	−0.1
1901	−2.0	0.5	−2.3	0.8	−0.1	1.0	0.4	−1.1
1902	1.2	0.8	1.5	1.1	1.7	0.7	0.0	−2.3
1903	−1.6	−0.1	−2.0	−0.2	−1.2	0.5	0.6	1.3
1904	−0.3	−0.4	−1.5	−0.5	1.0	−0.5	−0.2	0.8
1905	1.2	0.1	0.0	0.2	0.1	0.3	0.2	−0.1
1906	0.7	1.0	1.2	1.5	0.6	1.7	0.7	−2.1
1907	0.3	−0.6	−1.0	−0.8	−1.5	−0.7	−0.1	1.6
1908	−0.4	−0.2	−0.3	−0.2	2.4	0.4	0.5	1.2
1909	0.3	−0.9	−0.6	−1.3	1.0	−1.6	−0.7	1.7
1910	−0.2	−0.5	0.2	−0.6	−0.1	0.0	0.4	2.0
1911	2.0	0.1	0.6	0.2	−2.2	0.2	0.1	−0.2
1912	0.3	0.7	1.0	1.2	1.6	2.4	1.5	−0.2
1913	−1.0	0.2	−0.3	0.3	1.3	0.3	0.1	−0.5
1914	−0.6	0.6	−0.5	0.9	2.3	1.7	1.0	−0.5
1915	2.2	1.0	2.2	1.4	2.3	1.0	0.0	−3.1
1916	−0.1	−0.6	−0.5	−1.0	−0.1	−2.3	−1.6	−0.4
1917	−2.6	−1.3	−4.0	−1.8	−2.7	−1.3	−0.1	3.7
1918	0.2	−0.2	−0.5	−0.4	−0.7	−0.8	−0.5	0.0
1919	3.6	1.5	3.5	2.1	0.7	2.5	1.0	−3.1
1920	−0.1	0.9	0.7	1.3	2.3	1.4	0.5	−2.1
1921	2.1	0.5	2.6	0.7	1.3	0.1	−0.3	−1.9
1922	1.2	0.7	1.5	1.0	3.7	2.0	1.2	−0.4
δ=	1.26	0.59	1.67	0.86	2.08	1.11	0.61	1.43

HEAVY SNOWFALL OF JANUARY, 1929, AT DUBUQUE, IOWA

By H. MERRILL WILLS

[Weather Bureau Office, Dubuque, Iowa]

A new record has been set for all months by the heavy snowfall of January. The total fall of 34.3 inches is without precedent in the history of the station. The only previous monthly fall which approached this record was 32 inches in December, 1887. The heaviest single fall in 24 hours was 11 inches on the 4th and 5th. This is the largest single snowfall in the last 17 years. The accumulated average depth at the close of the month amounted to 20.1 inches, and this appears to have exceeded all previous records for the last 36 years, excepting one similar record of 20.5 inches in January, 1910. The snows of the last month have brought the winter's fall to date to 39.7 inches, which is more than a normal entire winter's fall. Practically the entire month's precipitation was from snow, amounting to 3.13 inches, which is the largest for January in 42 years.

The snows of the month were of unusual significance in the character of ground cover which resulted with its devastating effects upon street and highway transportation as well as damage to roofs and other property. Perhaps no snows have every developed greater persistency in accumulating and hardening upon pavements, rendering the operation of vehicles difficult and dangerous at all times after the first heavy fall, on the 4th and 5th. The conditions were decidedly aggravated along street-car lines where the rails became deep channels or ruts in the heavy masses of frozen snow which covered the streets from 6 to 12 inches thick generally and as much as 18 inches thick in places. These conditions steadily grew worse, and the city finally resorted to the use of snowplows, tractors, scarifiers, graders, picks, and trucks from the middle of the month on into February in an effort to

remove the snow and ice. The situation was somewhat improved when the month closed but still very bad generally.

More or less drifting occurred through the month which also interferred with street, highway, and railroad transportation. The first heavy snow, on the 5th, drifted some, causing general delays and blocking country roads for several days. Street-car service was paralyzed for a time, some lines not being able to resume operation for a day or two. Light to moderate snows fell at frequent intervals through the rest of the month, accompanied by considerable drifting which would refill where snow plows had removed the snow. Some interurban busses were unable to run at all during the rest of the month, especially north and east, due to blockades. Trains were frequently off schedule from one to several hours, and a 36-mile branch of one line was entirely closed for practically three weeks. Crews operating snow plows north of the city encountered drifts as deep as 10 feet. Colesburg, a small village about 30 miles northwest of Dubuque, was completely isolated for nearly three weeks. Snow plows operated vigorously day and night for practically a month in an effort to open the roads throughout the territory around Dubuque, and to clear the streets in the city.

Of course, the persistent cold weather was a heavy contributing factor in that only slight melting of the snow occurred and this was immediately followed by freezing and consequent hardening of the snow, which made its removal extremely difficult. Again, on the 22d light rain formed an incrustation upon the snow and also encouraged the hardening of the whole cover, which retarded melting and evaporation later and increased the difficulty of removal.

It was believed a week ago that $200,000 would be a conservative estimate of the loss to business and damage to property resulting from the snows of January in Dubuque and surrounding territory. It has just now been announced that the roofing concerns of the city have placed an estimate of $100,000 upon the damage to property resulting from accumulated snow on the roofs, alone. Gigantic icicles measuring from 5 to 15 feet in length and as large as a man's body have been a common sight about the city and many can still be seen at this writing hanging from the eaves, the most of them having been removed by workmen to prevent possible injury to life or property.

NOTES, ABSTRACTS, AND REVIEWS

An exceptional January.—January, 1929, was an exceptional month in several respects but primarily in the unusually irregular sequence and rate of movement of cyclones and anticyclones. The following details of two cases will illustrate this fact. The cyclone of the 3d–8th (see Chart III) came from the Pacific and entered the continent over the coastal waters of British Columbia and the State of Washington on the 3d, followed the course indicated on the above-mentioned chart was centered at Port Burwell, on Cape Chidley, which forms the headland of the south side of Hudson Strait where it debouches on Davis Strait, with central pressure of 28.02 inches at 7 p. m. of the 7th. Pressure at Godthaab, Greenland, at this time was 28.86 inches. The remnants of this immense depression of the barometer could be found three days later far to the westward over Hudson Bay, but the most remarkable case of the displacement of a cyclone center to the northwest by high pressure to the northeast took place between the morning of the 14th when the cyclone center was over Sable Island with pressure 29.38 inches, and the morning of the 19th when it was filling up over the west shore of Hudson Bay with pressure of 29.44 inches, at Churchill. The second cyclone was that of January 18–21. See path as traced on Chart III. Both of these cylones in the 24-hour movement from Kansas City, Mo., in approximately the geographical center of the United States traveled at very great speed and central pressure decreased 0.52 and 0.36 inch, respectively. The first one moved very close to 1,000 miles and the second approximately 1,500 miles. The dynamic considerations involved in this rapid movement and large diminution of central pressure would form the subject of special inquiry were the details of the process known. Unfortunately they are not available and only surface observations are at hand.

These show that the pressure distribution on January 18 was quite favorable to a rapid movement of the center, more so than on January 5. In both cases the centers moved into a region in which there was a rise in surface temperature of 20° F. or more in 24 hours.

Another exceptional feature of the month was the scarcity of snow over the eastern seaboard south of New England. In Washington, D. C., for example but 0.3 inch fell during the month and the winter's total is but 0.5 inch up to this writing, February 11. On the other hand snow was abundant in the northern border States and the Rocky Mountain region. See Chart VII.

Mean temperatures of the month were widely divergent; in the upper Missouri Valley they were as much as 10° F. below normal and in southeastern States 4° above. See Chart I. Evidently much cold air overlaid southern Canada and the northern border States. The trigger that served to release masses of this air in a southward gravitational flow was the eastward movement of cyclonic areas across the Rocky Mountains of which a relatively large number was noted, many of which failed in crossing the continent. It so happened that the great majority of these areas followed a course that took them northeastward across the Great Lakes. Since pressure over the western Atlantic off the Carolinas, as at Bermuda, was high throughout the greater part of the month cold air was prevented from entering the Atlantic seaboard to any marked extent. The daily changes were unusual, in one case an area of at least 29,000 square miles in extent experienced a rise of 20° or more in 24 hours and this was immediately followed by a change in the opposite direction in the ensuing 24 hours. These and other unusual changes that might be mentioned will give some idea of the tribulations of the forecaster who undertook to anticipate the weather of the month.—*A. J. H.*

Cold weather in Europe during January, 1929.[1]—Pressure was much above normal over the whole of western Europe and at Bermuda, the greatest excess being 24.2 mb. at Isafjord, while pressure was below normal over the North Atlantic, where the greatest deficit was 11.1 mb. at Horta. Temperature was below normal except in the north of Scandinavia and in Portugal, being as much as 6° F. below normal in south Sweden and at Spitsbergen, while precipitation totals were deficient except in Spitsbergen and eastern Sweden.

Heavy and continuous rains accompanied by thunder, snow, and hail storms during the first few days of the

[1] Reprinted from The Meteorological Magazine, London, February, 1929, page 24.

month resulted in floods in many parts of Italy. The Tiber is reported to have risen to 50 feet, making it the worst flood experienced in Rome since February, 1915. Other large towns to be severely affected were Pisa, Florence, and Naples. Cold weather with heavy falls of snow occurred generally over the whole of Europe even as far south as the Riviera during the first half of the month. At Majorca the temperature was almost down to freezing point but the weather was sunny. In Central Europe the snowfalls were so heavy that railway and telegraph communications were broken in several places. The ice on the Elbe above Hamburg was so thick that the river could be crossed on foot; navigation on the tributaries of the Rhine also came to a standstill about the 16th. For the first time since 1917 skating was permitted on the lakes in the Bois de Boulogne (Paris) on the 17th and 18th. After a milder spell lasting about three days heavy snow fell generally on the 25th, and as far south as the Riviera on the 25th, 27th, 28th. Severe cold was experienced during this time with violent storms in Yugoslavia.

On the 23d and 24th after a week of severe weather there was a heavy fall of snow in Jerusalem. Gales and snowstorms accompanied by high tides caused much damage along the northeastern coasts of Japan during the first week of the month.

In the same issue of The Meteorological Magazine, under the caption "The winter of December, 1928, and January and February, 1929" the following explanation of the severe cold in Europe during February, 1929, is given:

> At the beginning of February a large area of low pressure developed over the North Atlantic, and pressure over Iceland fell rapidly, but in the meanwhile an extraordinarily intense anticyclone had developed over northern Russia, pressure reaching nearly 1,060 mb. [31.30 inches] over the Urals on January 29. The anticyclone continued to advance westward, and has occupied northern Russia and the Baltic region during the first half of February. It is an offshoot of the great winter anticyclone of Siberia, with which it is connected by a ridge of high pressure in about 60° N. latitude, and on its southern side a great current of intensely cold air from Siberia drifted across Europe.
>
> The second week of February was accordingly intensely cold over central Europe, and at this writing [probably about February 15] the cold shows no sign of abating. * * *

ATMOSPHERICS AND TROPICAL CYCLONES

By FATHER E. GHERZI, S. J., *in charge weather and seismic services*

[Zi-ka-wei Observatory (near Shanghai), China]

In a research published in 1923 concerning the radio reception in Zi-ka-wei of the Bordeaux press and time signals, during the typhoon season, we had the occasion of advancing that the tropical cyclone, contrary to the extratropical cyclone, is composed only of equatorial air.

Further data obtained from ships, which had passed through the center of these powerful and destructive centers, confirmed our first idea and recently also the Japanese meteorologists have agreed that in a typhoon there is no temperature discontinuity. (Compare, for instance, The Memoirs of the Imperial Marine Observatory Kobe, on the Typhoon of the Far East, by Yosiki Horiguti. 1926 to 1928.)

We had advanced our theory on the ground that in the radio reception, those disturbances so well known to all the radio operators, which have been called "statics' or "strays" or "atmospherics," had really decreased with the approach, and especially in the central area of these tropical cyclones.

In an article published by the Air Ministry of London, in the Marine Observer through the kindness of the marine superintendent, Commander L. A. Brooke-Smith, in August, 1925, we asked that similar researches might be made elsewhere in order to compare the results.

Later on the U. S. S. cutter *Kittery*, in a campaign around the Antilles had the occasion of making some observations, with a recording loop receiver, not far from the central zone of the so-called "Miami cyclone" (namely a typhoon or tropical cyclone).

The conclusions given in a "Notice" published in the Pilot Charts issued by the United States Hydrographic Office, showed that in that cyclone the "atmospherics" had been very strong all over the typhoon area.

The ship herself had not been in the center and even not in the real stormy region as her barometer's lowest reading had only fallen to 29.56 inches. This barometric pressure (every sailor will admit) is quite near the normal value for the tropical regions during these months of cyclones.

So much that we declined to admit that the experiences of the U. S. S. *Kittery* did really consider the problem long the line which we think is the right one, and which we have been able to follow, owing to the kindness of the captains of the ships which had really gone through the centers of the typhoons quoted by us. (Compare The Marine Observer, August, 1925, and August, 1928.)

Since Sir Napier Shaw in his Manual of Meteorology, Volume II page 371, edited in Cambridge in 1928 [1] seems to admit that the U. S. S. *Kittery* reports would contradict, in some ways, our own experiences for the far eastern seas, we think convenient to state again how the research should be conducted for making a comparison with our own possible.

In the typhoon region (taking this in a general sense) three concentric zones should be admitted.

1. The zone where the circulation of the wind begins to be cyclonic. There we have found "atmospherics" and local thunder storms, which are, we think, by and by dissolved by the approach of the real typhoon zone.

2. The zone where the cyclonic circulation is real and fresh but the barometer has not yet begun the V characteristic of the typhoon barometric curve and the value of the pressure is yet relatively normal, just as in the case of the U. S. S. *Kittery*, concerning the Miami cyclone.

There "atmospherics" are also present but they have been reported as relatively decreasing.

3. The central zone (not only the central part with its characteristic "calm"), with its steep barometric gradient showing a V on the barographic record.

There, according to the examples we have been able to quote in our articles, the "atmospherics" had almost disappeared and in some cases have been completely absent, although there had been heavy and blinding rain squalls and hurricane winds during the time of the observation.

These are the facts already quoted. We would like to know how things happened on ships having gone through the center of the cyclone, in low latitudes,[2] over

[1] "* * * Gherzi has cited instances of steamers passing through centers of typhoons and experiencing no atmospherics * * *. On the other hand reception of Arlington was impossible (owing to static) when the Nassau and Miami hurricanes were between Arlington and U. S. S. *Kittery* in the West Indies seas."

[2] Once a tropical cyclone is on the northeasterly course, some envelopment by polar cold air should be admitted, with corresponding "atmospherics" in the radio reception.

the Antilles region. We are afraid some ships had this trying experience and their reports should be compared with those of our far eastern seas.

Coming now to the way of finding the "atmospherics" region by means of a revolving loop, either close to the center, but not in the center, or some distance away, as in the case of the U. S. S. *Kittery*, everyone who has been practicing with this kind of instrument will agree that it shows only a direction, but not a fixed and special place along that direction. In the case of the U. S. S. *Kittery* reports as the ship was outside of the real typhoon zone the registration showed only that there was a region with "atmospherics" around the center, or, may be, beyond the center, even very far, but not in the center.

Even using two loops, these would point to a possible ring of atmospherics around the center just as we agree it can exist in zones 1 or 2.

Only by passing through the center, a very disagreeable experience (we quite admit it), can the phenomenon we have quoted, be controlled and checked elsewhere?

I will add a few words concerning the meteorological aspect of the typhoon central area (not the center itself) which may help to explain this absence or decrease of the "atmospherics."

First of all the rainfall distribution, at least at sea, seems to be practically homogeneous all round the center. In the center itself it ceases, as a rule. That shows that in a tropical storm there is no squall line. This peculiarity, we think, is of great importance.

In the second place, the intensity of the wind, at sea, is also practically equally great all round the center. There is not the sharp distinction which is found for the extratropical cyclones, where in the southeastern and southern sectors the wind is rather light, with warmer temperature and prevailing fog. There is no real fog in a typhoon region. The rain is blinding and thick, but that is not what the meteorologists call mist or fog.

These two points converge in showing that the typhoon core is rather homogeneous and this homogeneity seems to us to explain the absence of atmospherics in the center itself, once more according to ships that passed through it and kindly reported to us their radio experiences.

New edition of Physics of the Air.—Our readers will be interested in knowing that a new edition of this standard work by Dr. W. J. Humphreys has been published by the McGraw-Hill Book Co. of New York. This is not a mere reprint of the old edition. A new section on meteorological acoustics has been included. A discussion of atmospheric turbulence and a much fuller account of the relation of wind velocity to height have been given, and numerous other topics either enlarged or newly added, thus bringing the book down to date.—*A. J. H.*

The Norwegian Weather Service.—The 1927 yearbook of the Norwegian Meteorological Institute, just received, tells of the 122 stations of the Norwegian weather network, and gives hourly values of pressure, temperature, precipitation, and atmosphere electric potential gradient for Oslow or Aas, the term observations for 10 stations and the monthly and annual résumé for all stations. Departures from the normal sea temperatures along the coast and observations at Green Harbour, Spitzbergen, and on Jan Mayen, are included in appendixes. Of the 122 stations, 57 have mercurial barometers, three-fourths of these with millibar scales, 71 have psychrometers or hair hygrometers, about 50 operate barographs, 20 have thermographs, and 6 have hygrographs. The equipment of 51 of the stations is simply a dry thermometer. The instruments are exposed in window shelters except for the stations with thermographs.

The daily precipitation at 186 rainfall stations is published in Nedbøriakttagelser i Norge for 1927, as is also the daily snowfall for 48 stations. A map (1:1,300,000) shows in detail the distribution of rainfall for the year, from maxima of 2,400 to 2,600 mm. at 5 points near the southwest coast and 1 farther north, to minima of under 800, 600, or 400 in the southern and central interior, and under 300 in the northern interior. The maximum rainfall for the year was at Vassbo, in the extreme southwest, latitude 58° 41′, longitude 6° 21′ E., altitude 78 m., and 35 km. from the coast. In the 11 months, January to November, the precipitation was 2,599 mm. (102 inches) on 244 days (with 0.1 mm. or more). The December record was zero, and at Hogstad, near by, only 1 mm. (normal 229). Nineteen hundred and twenty-seven was a relatively dry year, with little or no precipitation in the cold December, even on the rainy coast. At Bergen there was but 4 mm., compared with a normal of about 200.

The normals of rainfall for Norway have been brought down to date and published by the Meteorological Institute in 1928. Three stations have over 3,100 mm. on the average: Kvitingen, 3,120 (latitude 60° 28′, longitude 5° 24′ E., altitude 315 m.); Haukeland, 3,147 (124 inches) (latitude 60° 50′, longitude 5° 34′ E., 240 m.); and Hovlandsdal, 3,135 mm. (latitude 61° 14′, longitude 5° 26′ E., altitude 122 m.). These are all near Bergen, and 30 to 40 km. from the open sea. Vassbo has too short a record for a normal yet.—*C. F. B.*

The typhoons of 1927.—In the Far East tropical cyclones are known as "typhoons." Father E. Gherzi, S. J., has presented to the general chamber of commerce of Shanghai, China, a report upon the typhoons of 1927 for which warnings were issued by the Zi-Ka-Wei Observatory near Shanghai. Thirty-three typhoons of all classes were located on the synoptic charts of the observatory but only 23 of them have been definitely tracked. The distribution by months is as follows: February, 1; March, 2; April, 0; May, 2; June, 1; July, 2; August, 4; September, 5; October, 4; November, 1; and December, 1.

The inference is that the remaining 10 storms were not so clearly in evidence as to warrant an attempt to plot them.

It is interesting to note that the observatory classes as a typhoon all tropical cyclones that have their origin south of the Tropic of Cancer. In a recent compilation made by forecaster Charles L. Mitchell of the United States Weather Bureau it was shown that only 72 per cent of all of the tropical cyclones that were located on the weather charts for North America of the last 50 years reached full hurricane intensity. Hurricane intensity is defined as a central, or near central, pressure of 29 inches and a wind velocity near the center of at least 60 miles per hour. It would seem that in the Orient about the same proportion holds good.—*A. J. H.*

Tornadoes and line squalls on January 18, 1929.—On this date a small tornado occurred in Scott County, Mo., in which three persons lost their lives and the property damage was about $15,000. On the same date a line squall swept over Kentucky in which four persons were killed and five injured and the total property loss was estimated at $1,250,000. The details appear in the table of severe wind storms on another page.

Wettest November in Southern Panama.—The Pacific slope of Panama in the cool months of the Northern Hemisphere is usually the lee slope, under the general westerly or northerly winds of this month, and is therefore much less wet on the average than is the northern, windward half of the Isthmus. (See L. T. Chapel, Winds and Storms on the Isthmus of Panama, Monthly

Weather Review, December, 1927, pp. 519–530). The Monthly Meterological Report for November, 1928, of the Department of Operation and Maintenance of the Panama Canal, shows for this month a reversal of the usual pressure gradient, and with it the wettest month on record for the Pacific slope of Panama. The monthly mean bihourly pressure was 29.835 inches at Balboa Heights and 29.831 at Cristobal. The small excess of pressure at the Pacific coast over that at the Atlantic and the consequent light winds permitted probably greater raininess on the Pacific slope than if the winds had been stronger, for the rains of Panama are typically of the local shower type. The rainfall of the Pacific section was generally twice the average, and ranged from 9.91 at Taboga, which is normally the driest place in Panama, to 44.29 inches at Mariato. Balboa Heights had 20.51 inches of rainfall, more even than Gatun, that normally has twice the rainfall of Balboa. Rain fell on 23 days at Balboa and on 30 days at Cristobal.

The failure of the norther of November 23 to reach Panama after coming as far as Costa Rica, where it was apparently responsible for the devastating floods at this time, may have been due to the reversed pressure gradient over Panama this month. However, it is worthy of note that the heaviest rain of the month at San Blas Farm, in northern Panama, 7.20 inches, fell on November 23. [This was a quarter of the entire rainfall at that place for November.]—*C. F. B.*

Meteorological summary for Chile for December and also the year 1928 (by J. Bustos Navarrete, Observatorio del Salto, Santiago, Chile).—December.—Atmospheric circulation over the South Pacific Ocean was a little more active in the first and last decades of the month. The depressions most important in producing unsettled weather and rains in the south were those charted during the following periods: 1st to 3d, 4th to 5th, 6th to 7th, 18th to 19th(?), and 28th to 30th. The condition of foul weather and rain between Chiloe and Talca during the first days of the month was a feature well worth mention.

The most important anticyclonic centers, accompanied by fine weather, showed the following positions and movements: 1st to 14th, from Coquimbo to Juan Fernandez, Chiloe, and Argentina; 17th to 18th, over Chiloe; 19th to 20th, from Juan Fernandez to Chiloe; and 24th to 27th, from Chiloe toward Argentina.

In the central zone the weather was variable in the first decade, but uniform in the second and third decades. In the southern zone there was an increase in precipitation; at Valdivia the total for the month was 9.17 inches.

Year 1928.—The slight anomalies presented were unequal distribution of rainfall which occurred mainly in the central zone between April and June, and gradual increase in temperature and dryness beginning with July. On the whole this year had more precipitation and somewhat lower temperature than the year 1927.

The months of January and February had lower temperatures than the same months of the preceding year; the summer was more moderate. The winter months were cold, but not severe, with lowest mean temperature in June. Beginning with July there came an increase in temperature, a rare occurrence since normally the minimum appears in July or August.

At Santiago the highest temperature was 91° on February 22 and the lowest 28° on June 25 (lowest in Chile, 11° at Caracoles on June 24). The total annual precipitation was 13.82 inches, June being the rainiest month with 5.94 inches. In the cordilleras the average depth of snowfall was 3 meters (9.8 feet).

The most notable phenomena of the year were the torrential rains occurring at the beginning of April between Curico and Talca, 5.50 inches in 48 hours; in the mountain region snowfall was extraordinarily heavy and caused great damage. The heavy downpour at Valdivia on June 9 gave 6.97 inches in 24 hours.

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Über die Zirkulationen kalter und warmer Luft zwischen hohen und niedrigen Breiten. Wien. 1928. p. 189–225. figs. 24½ cm. (Sitzungsber. Akad. der Wissensch. Wien. Mathem.-naturw. Kl. Abt. IIa, 137. Bd. 3. und 4. Heft. 1928.)

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Om vindskalor och vindmätare i Svensk meteorologi. Sur les échelles de vent et les anémomètres en Suède. Stockholm. 1928. 16 p. illus. 31½ cm. (Medd. från Stat. met.-hydrog. anst. Bd. 4, n: o 6.)

Ower, E.
Measurement of air flow. London. 1927. vii, 199 p. illus. 22½ cm.

Pettit, Edison.
Comparative physical properties of sunlight and light from artificial sources. p. 110–118. figs. 23½ cm. (Repr.: Trans. 24th annual meeting Nat. tuberculosis assoc.)

Riem, Johannes.
Die Sintfut in Sage und Wissenschaft. Hamburg. 1925. 194 p. plates. map (fold.) 22 cm. (Natur. und Bibel in der Harmonie ihrer Offenbarungen. Buch 4.)

Sifontes, Ernest.
La pluie au Vénézuéla (Sud-Amérique) (1925–1926). Paris. 1928. 10 p. fig. 27½ cm. (Extr.: La mét., août 1928.)

Trinkler, Emil.
Afghanistan. Eine landeskundliche Studie auf Grund des vorhandenen Materials und eigener Beobachtung. Gotha. 1928. vi, 80 p. figs. plates (part fold.) 27½ cm. ("Petermanns Mitteil.," Ergänzungsh. Nr. 196.) [Das Klima, p. 33–36.]

SOLAR OBSERVATIONS

SOLAR RADIATION MEASUREMENTS DURING JANUARY, 1929

By HERBERT H. KIMBALL, Solar Radiation Investigations

For a description of instruments and their exposures at the several observing stations the following references may be consulted:

Washington, D. C., Mo. Wea. Rev., **53:** 318, July, 1925.

Madison, Wis., Mo. Wea. Rev., **44:** 2, Jan., 1916; **44:** 180, Apr., 1916.

Lincoln, Nebr., Mo. Wea., Rev., **44:** 2, Jan. 1916; **44:** 179, Apr., 1916.

Chicago, Ill., Mo. Wea. Rev., **51:** 533, Oct. 1923.

New York, N. Y., Mo. Wea. Rev., **53:** 29, Jan., 1925.

Twin falls, Idaho, Mo. Wea. Rev., **55:** 29, Jan., 1927.

An account of the method of obtaining and reducing the radiation measurements will be found in the following references:

Marvin pyrheliometer, Mo. Wea. Rev., **47:** 769, Nov., 1919.

Callendar pyrheliometer, Mo. Wea. Rev., **42:** 474, Aug., 1914.

W. B. thermoelectric pyrheliometer, Mo. Wea. Rev., **51:** 239, May, 1923.

Moll pyrheliometer, Mo. Wea. Rev., **54:** 381, Sept., 1926.

On October 6, 1928, a Moll thermopile, recording on an Engelhard microammeter, was installed at Fresno, Calif. The pyrheliometer is exposed at the west corner of the roof of the building in which the Weather Bureau office is located, on a small stand slightly higher than the roof parapet. The register is on a table in the Weather Bureau office room, which is on the top floor of the building.

The coordinates of the Weather Bureau office are as follows: Latitude, 36° 43′ north; longitude, 119° 49′ west of Greenwich; altitude of pyrheliometer, 350 feet above sea level, 85 feet above ground.

The San Joaquin Valley of California, in which Fresno is located, had an exceptionally dry summer in 1928, practically no rain falling in the interval April to October. In consequence the soil was very dry and enough was taken up by the wind to fill the air with dust.

The effect of the dust is seen in the atmospheric transmission of radiation as derived from solar radiation measurements made by me with a Smithsonian Silver Disk pyrheliometer, and summarized in Table 3. In the same table is included a summary of measurements made by the same instrument on March 14, 1920. Note that the atmospheric depletion in October was in excess of that in March by about 10 per cent in the early morning, 7 per cent at noon, and 1 to 2 per cent in the afternoon.

Table 1 shows that solar radiation intensities during January averaged close to normal values for the month at Washington, D. C., and Madison, Wis., and slightly above the normal at Lincoln, Nebr.

Table 2 shows that the total solar radiation received on a horizontal surface directly from the sun and diffusely from the sky was below the January normal at the five stations for which normals have been determined, the deficiency being marked at Lincoln.

Skylight polarization measurements made at Washington on two days give a mean of 58 per cent, with a maximum of 59 per cent on the 11th. These are slightly below the corresponding average values for Washington in January. At Madison no measurements were obtained during the month, as the ground was covered with snow.

TABLE 1.—*Solar radiation intensities during January, 1929*

[Gram-calories per minute per square centimeter of normal surface]

Washington, D. C.

Date	Sun's zenith distance: 8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass: A. M.					P. M.				Local mean solar time
	e.	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Jan. 2	2.74				1.45						1.60
Jan. 3	1.60		0.80		1.19						1.78
Jan. 4	2.87	0.57	0.68	0.93	1.00						2.87
Jan. 7	1.88	0.78	0.90	1.09				1.11	0.89	0.73	1.78
Jan. 8	0.86			1.20	1.39						0.74
Jan. 12	1.37	0.76	0.92	1.13	1.32			1.15	1.01	0.90	1.37
Jan. 19	9.45				1.27			1.01	0.88	0.80	5.79
Jan. 23	4.75		0.92	1.12	1.28		1.37	1.17	1.03	0.98	2.49
Jan. 26	2.06	0.78	0.88	1.05	1.25		1.27	1.05	0.87	0.78	2.16
Jan. 29	1.32	0.80	0.90	1.05	1.19			1.03	0.77	0.64	1.32
Jan. 30	1.45	0.45	0.58	0.77	1.11		1.04	0.70			1.19
Means		0.69	0.82	1.04	1.24		1.23	1.03	0.91	0.86	
Departures		−0.04	−0.02	+0.03	+0.01		±0.00	±0.00	+0.03	+0.01	

Madison, Wis.

Jan. 3	2.16			1.12							2.06
Jan. 7	0.38	1.11	1.22	1.35				1.34			0.56
Jan. 11	2.16							1.29			1.52
Jan. 12	1.02							1.21			1.68
Jan. 15	0.38	1.04	1.13								0.64
Jan. 21	1.24			1.09							2.06
Jan. 23	0.53	0.98	1.08	1.21							0.71
Jan. 25	1.24							1.21			0.79
Jan. 28	0.46	0.91	1.04	1.23	1.38			1.22			0.91
Jan. 29	1.12							1.03			1.24
Jan. 31	0.79		1.02	1.22	1.44			1.25			0.74
Means		1.01	1.10	1.20	(1.41)			1.22			
Departures		+0.05	+0.02	−0.03	+0.05			+0.01			

Lincoln, Nebr.

Jan. 3	2.74								0.88	0.77	2.36
Jan. 8	1.96		1.00	1.17				1.12	1.05	0.90	3.45
Jan. 11	0.96	1.19	1.25	1.35				1.31	1.14	0.97	0.74
Jan. 25	0.43		1.26	1.38				1.15	1.06		0.58
Jan. 31	0.66		1.15	1.23	1.40		1.41	1.21	1.03	0.86	1.02
Means		(1.19)	1.16	1.28	(1.40)		(1.41)	1.20	1.03	0.88	
Departures		+0.25	+0.11	+0.09	+0.02		−0.01	+0.03	−0.02	−0.04	

[1] Extrapolated.

TABLE 2.—*Total solar radiation (direct+diffuse) received on a horizontal surface*

[Gram-calories per square centimeter]

Week beginning	Average daily radiation: Washington	Madison	Lincoln	Chicago	New York	Twin Falls	Fresno	Average daily departure from normal: Washington	Madison	Lincoln	Chicago	New York
1929	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Jan. 1	148	139	168	86	83	189	117	−4	+2	−16	+8	−24
Jan. 8	180	133	153	68	112	248	118	+23	−15	−39	−12	+6
Jan. 15	146	143	159	86	92	189	277	−13	−18	−39	+3	−23
Jan. 23	144	172	168	95	156	180	272	−37	−15	−50	−11	+20
Deficiency since first of year on January 28								−217	−322	−1,008	−84	−147

TABLE 3.—*Solar radiation intensities and atmospheric transmission coefficients at Fresno, Calif.*

Date	Sun's zenith distance								
	0°	48°.3	60°.0	66°.5	70°.7	73°.6	75°.7	77°.4	78°.7
	Air mass								
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
	Solar radiation (Gram-calories per minute per square centimeter of normal surface)								
1928—A. M.									
Oct. 6	1.36								
Oct. 7	1.39	1.22	1.10	0.94	0.81				
Oct. 8	1.42	1.25	1.11	1.04	0.92				
Oct. 10				1.05					
Means	1.39	1.24	1.10	1.01	0.86				
1920									
Mar. 14	1.52	1.42	1.34	1.26	1.18	1.11	1.05	0.98	0.91
1928—P. M.									
Oct. 6		1.26	1.16	1.07	0.99	0.92	0.85		0.72
Oct. 7		1.28	1.17	1.10	1.03				
Oct. 8		1.29	1.20	1.13	1.01				
Means		1.28	1.18	1.10	1.01	0.92	0.85		0.72
1920									
Mar. 14		1.42	1.33	1.24	1.15	1.07	1.00	0.93	0.87
	Atmospheric transmission								
A. M.—October	1.01/1.24 = 0.815			0.86/1.10 = 0.782					
March	1.26/1.42 = 0.887			1.18/1.34 = 0.881					
P. M.—October	1.10/1.28 = 0.859			1.01/1.18 = 0.856			0.72/0.85 = 0.847		
March	1.24/1.42 = 0.873			1.15/1.33 = 0.865			0.87/1.00 = 0.870		

POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. C. S. Freeman, Superintendent U. S. Naval Observatory. Data furnished by Naval Observatory, in cooperation with Harvard, Yerkes, and Mount Wilson Observatories. The differences of longitude are measured from central meridian, positive west. The north latitudes are plus. Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere. The total area, including spots and groups, is given for each day in the last column]

Date	Eastern standard civil time	Heliographic			Area		Total area for each day
		Diff. long.	Longitude	Latitude	Spot	Group	
1929	h. m.	°	°	°			
Jan. 1 (Mount Wilson)	14 5	−31.0	237.7	−11.0		28	
		−7.0	261.7	+15.0	4		
		0.0	268.7	−20.0		35	
		+3.0	271.7	+10.0		19	
		+23.0	291.7	+8.0		253	
		+40.0	308.7	+20.0		43	
		+60.0	328.7	+5.0		13	395
Jan. 2 (Naval Observatory)	11 40	−81.0	175.7	+12.0	201		
		−56.5	200.2	+11.5	9		
		−18.0	238.7	−9.5		46	
		+12.0	268.7	−19.0		77	
		+35.0	291.7	+8.5		340	
		+50.5	307.2	+21.5		62	735
Jan. 3 (Naval Observatory)	11 35	−67.0	176.6	+12.5		247	
		−5.5	238.1	−8.5	15		
		+25.5	269.1	−18.5		46	
		+33.5	277.1	+10.0	22		
		+49.5	293.1	+8.5		370	
		+63.5	307.1	+21.5		90	790
Jan. 4 (Naval Observatory)	11 39	−53.5	176.9	+12.5		185	
		−1.0	229.4	+10.5		12	
		+7.5	237.9	−9.0		22	
		+40.0	270.4	−17.0	28		
		+47.0	277.4	+9.0		77	
		+66.0	296.4	+9.0	185		
		+78.5	308.9	+22.5	31		540
Jan. 5 (Mount Wilson)	16 00	−60.0	154.8	−14.0		7	
		−37.0	177.8	+12.0		212	
		−16.0	198.8	−13.0		7	
		+63.0	277.8	+9.0		37	
		+73.0	287.8	+7.0		84	347
Jan. 6 (Naval Observatory)	11 55	−51.0	152.9	−11.5		62	
		−39.0	164.9	+16.0	9		
		−27.5	176.4	+11.5	154		
		+12.0	215.9	−0.5		46	
		+28.0	231.9	+9.0	15		
		+74.0	277.9	+8.5		247	533

Positions and areas of sun spots—Continued

Date	Eastern standard civil time	Heliographic			Area		Total area for each day
		Diff. long.	Longitude	Latitude	Spot	Group	
1929—Continued	h. m.	°	°	°			
Jan. 7 (Naval Observatory)	11 52	−36.0	154.8	−11.5		93	
		−27.5	163.3	+18.0		77	
		−14.5	176.3	+11.5	139		
		+4.5	195.3	+11.5		46	
		+25.5	216.3	−1.0		108	
		+38.5	229.3	+10.0		108	571
Jan. 8 (Naval Observatory)	11 50	−81.5	96.1	+18.0	123		
		−22.5	155.1	−11.5		139	
		−14.0	163.6	+18.0		62	
		−1.5	176.1	+12.0	123		
		+17.5	193.1	+12.5		77	
		+40.0	217.6	−1.0		62	
		+53.5	231.1	+9.0		108	694
Jan. 9 (Naval Observatory)	10 56	−67.5	97.5	+18.0	123		
		−9.5	155.5	−11.5		62	
		+11.5	176.5	+11.5	108		
		+30.5	195.5	+12.5		62	
		+43.0	208.0	−12.0		31	
		+52.5	217.5	−1.0		77	
		+68.0	233.0	+8.5		108	571
Jan. 10 (Naval Observatory)	11 46	−56.0	95.3	−15.0		6	
		−53.5	97.8	+18.0		123	
		+3.0	154.3	−12.0		77	
		+25.0	176.3	+12.0	77		
		+42.0	193.3	+13.0	15		298
Jan. 11 (Naval Observatory)	12 27	−77.0	60.8	+7.5		201	
		−39.5	98.3	+19.0		77	
		−37.0	100.8	−15.0	15		
		+17.5	155.3	−12.0		62	
		+38.0	175.8	+12.0	46		401
Jan. 12 (Naval Observatory)	11 46	−63.0	62.0	+8.0		370	
		−26.5	98.5	+19.5		77	
		−24.5	100.5	−14.5		31	
		−10.0	115.0	−7.5		93	
		+21.5	146.5	−20.0	31		
		+30.0	155.0	−12.0		62	
		+51.5	176.5	+12.0	46		710
Jan. 13 (Naval Observatory)	11 41	−49.5	62.4	+7.5		509	
		−13.0	98.9	+20.0		123	
		−10.5	101.4	−14.5		31	
		+4.5	116.4	−9.0		108	
		+32.5	144.4	+5.0		28	
		+43.0	154.9	−13.0		9	
		+64.0	175.9	+12.0	6		814
Jan. 14 (Naval Observatory)	11 54	−35.0	63.6	+6.5		494	
		0.0	98.6	+18.5		62	
		+4.5	103.1	−15.0		31	
		+16.5	115.1	−11.0		216	
		+47.0	145.6	+3.5		46	849
Jan. 15 (Harvard)	14 2	−21.0	63.0	+7.0		857	
		+15.0	99.0	+20.0		164	
		+26.5	110.5	−22.5		181	
		+32.5	116.5	−10.0		376	1,578
Jan. 16 (Naval Observatory)	11 12	−72.0	0.6	−11.0		355	
		−35.0	37.6	+6.0		15	
		−10.0	62.6	+7.5		910	
		+25.5	98.1	+18.5		77	
		+36.5	109.1	−22.5		93	
		+43.0	115.6	−9.5		247	1,697
Jan. 18 (Naval Observatory)	14 51	−78.5	325.8	+5.5	15		
		−40.0	4.3	−10.5		401	
		+19.5	63.8	+8.0		679	
		+54.0	98.3	+20.0		31	
		+63.5	107.8	−22.0		31	
		+69.5	113.8	−9.5	31		1,188
Jan. 19 (Naval Observatory)	11 54	−67.0	325.8	+6.0		46	
		−27.5	5.3	−10.0		602	
		+31.5	64.3	+7.5		602	1,250
Jan. 20 (Naval Observatory)	11 41	−76.5	303.2	+4.0	77		
		−55.0	324.7	+5.5		170	
		−14.0	5.7	−10.5		432	
		+45.5	65.2	+7.5		463	1,142
Jan. 21 (Naval Observatory)	11 49	−68.5	298.0	+6.0		355	
		−42.5	324.0	+5.5		201	
		0.0	6.5	−11.0		370	
		+58.0	64.5	+7.5		370	1,296
Jan. 22 (Harvard)	11 42	−53.5	300.0	+7.0		542	
		−28.5	325.0	+8.0		329	
		+13.0	6.5	−8.5		450	
		+73.0	66.5	+8.5		423	1,744
Jan. 23 (Naval Observatory)	11 59	−43.0	297.0	+7.5		309	
		−15.0	325.0	+6.5		139	
		+27.5	7.5	−10.0		231	679
Jan. 24 (Harvard)	12 16	−28.5	298.5	+7.5		495	
		−2.0	325.0	+6.5		272	
		+42.0	9.0	−11.0		369	1,136
Jan. 25 (Mount Wilson)	18 35	−12.0	298.1	+10.0		146	
		−8.0	302.1	+5.0		117	
		+15.0	325.1	+5.0		50	
		+57.0	7.1	−11.0		205	518

Positions and areas of sun spots—Continued

Date	Eastern standard civil time	Heliographic			Area		Total area for each day
		Diff. long.	Longitude	Latitude	Spot	Group	
1929—Continued	h. m.	°	°	°			
Jan. 26 (Naval Observatory).	12 00	−2.0	298.5	+8.0	.....	170	.....
		+26.0	326.5	+5.5	.....	31	.....
		+65.0	5.5	−11.0	.....	340	541
Jan. 27 (Harvard)	13 10	+13.5	299.5	+8.0	.....	124	.....
		+28.0	314.0	+12.0	17	.....	.....
		+81.5	7.5	−10.0	.....	710	851
Jan. 28 (Naval Observatory).	12 12	+22.5	296.6	−22.0	12	.....	.....
		+26.0	300.1	+7.5	.....	185	.....
		+49.0	323.1	+6.5	15	.....	212
Jan. 29 (Naval Observatory).	11 53	+40.0	301.1	+7.5	.....	77	.....
		+61.5	322.6	+6.0	15	.....	92
Jan. 30 (Naval Observatory).	12 1	−7.5	240.4	−4.5	.....	123	.....
		+54.5	302.4	+8.0	77	.....	200
Jan. 31 (Naval Observatory).	11 15	−71.0	164.1	+5.0	62	.....	.....
		+6.0	241.1	−5.0	.....	154	.....
		+67.0	302.1	+8.5	77	.....	293
Mean daily area for January.	.....	.....	.....	.....	.....	.....	756

PROVISIONAL SUN-SPOT RELATIVE NUMBERS [1] FOR JANUARY, 1929

[Data furnished through the courtesy of Prof. W. Brunner, University of Zurich, Switzerland]

January, 1929	Relative numbers	January, 1929	Relative numbers	January, 1929	Relative numbers
1	.....	11	44	21	[2] 77
2	.....	12	[3] M 82	22	65
3	64	13	[4] 82	23	102
4	66	14	[4] 90	24	([4])
5	45	15	77	25	51 ?
6	[3] E 39	16	113	26	([2])
7	61	17	([2])	27	55
8	[4] 73	18	89	28	20
9	80	19	77	29	22
10	[4] 74	20	92	30	[3] M 29
				31	[4] 31

Mean, 26 days, 65.4.

[1] Dependent alone on observations at Zurich University and its station at Arosa.
[2] Passage of a large group through the central meridian.
[3] New formation of a larger or average-sized center of activity; E, on the eastern part of the sun's disk; M, near the central meridian.
[4] Passage of an average-sized group through the central meridian.

AEROLOGICAL OBSERVATIONS

By L. T. SAMUELS

Free-air temperatures for the month averaged below normal except at the eastern stations, Due West and Washington. (Table 1.) The negative departures were greatest at Ellendale where they were excessive but were successively smaller at the stations farther south.

Free-air relative humidities averaged above normal in many cases and particularly in the upper levels at Royal Center where the departures were unusually large. At this station and at Ellendale where negative temperature departures were greatest the total precipitation for the month exceeded all previous amounts for January. In this connection it is noted that the average vapor pressures in the higher levels at Royal Center were appreciably above normal notwithstanding the fact that the mean temperatures at the same levels were considerably below normal.

Table 2 shows the monthly resultant wind velocities to have been close to normal and the directions having in general a more northerly or less southerly component than normal.

It is interesting to note the Groesbeck kite record of the 27th in connection with the dissipation of a solid layer of stratus clouds over that station at 5:40 a. m. The balloon observation at that time showed the height of their base to be 500 meters and the wind at this elevation from the southwest. By 7:20 a. m. these clouds had dissipated and the kite observations showed the wind at 500 meters to be from the west although the surface wind continued from the southwest. This station was at the time in front of a wind shift line and it is evident that with the change in wind direction at the 500-meter level, dry air from a totally different source arrived and resulted in the dissipation of the clouds. The shift to northerly at the surface, however, did not occur until several hours later.

An interesting condition of snow flurries in a high-pressure area occurred at Royal Center on the 15th. The kite flight made during the occurrence of this precipitation revealed an inverted lapse rate from the ground to the cloud level at 500 meters, practically isothermal from the base to the top of the clouds at 850 meters, superimposed by another inversion layer to 1,850 meters. The occurrence of light snow flurries falling from air actually warmer than the air below it, is a result of the neighboring Great Lakes. These flurries form over the relatively warm water and later extend some distance beyond over the land which is considerably colder than the water.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during January, 1929*

TEMPERATURE (° C.)

Altitude m. s. l.	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)		Washington, D. C.[1] (7 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Meters												
Surface	0.0	−3.2	4.8	−0.9	−17.7	−6.6	8.4	+0.4	−8.5	−4.2	−1.6	−0.8
250	−0.1	−3.2	4.8	−0.8	.....	.....	8.0	+0.2	−8.6	−4.1	−1.8	−0.8
500	−1.0	−3.7	5.3	−0.1	−17.9	−6.9	7.2	−0.5	−9.9	−4.4	−2.3	−1.0
750	−1.1	−3.6	5.8	+0.7	−17.6	−7.4	6.6	−0.7	−10.3	−4.7	−2.7	−1.0
1,000	−0.1	−2.7	5.4	+0.9	−16.6	−7.8	6.5	−0.8	−9.6	−4.1	−3.5	−1.1
1,250	0.4	−2.2	4.7	+0.9	−15.9	−7.9	6.6	−0.4	−9.6	−4.0	−4.2	−1.1
1,500	0.3	−2.0	3.7	+0.8	−15.8	−7.7	6.0	−0.4	−9.8	−3.8	−4.3	−0.8
2,000	−0.6	−1.5	1.4	+0.4	−16.4	−6.8	4.7	0.0	−10.6	−3.6	−4.5	0.0
2,500	−2.6	−1.3	−0.9	+0.1	−17.8	−6.0	2.6	0.0	−11.9	−3.0	−5.5	+0.6
3,000	−4.9	−1.1	−2.9	+0.3	−19.9	−5.5	0.4	+0.1	−14.3	−3.1	−6.8	+1.1
3,500	−7.5	−1.1	−5.1	+0.3	−21.4	−4.2	−2.8	−0.3	−16.8	−3.1	−8.4	+1.4
4,000	−10.8	−1.5	−8.4	−0.1	−24.0	−4.2	−5.6	−0.3	−18.9	−3.6	−10.2	+1.4
4,500	.....	.....	−12.3	−1.1	.....	.....	.....	.....	−21.2	−3.4	−11.9	+1.4

RELATIVE HUMIDITY (%)

Surface	73	+3	73	+5	78	−3	75	−2	76	−3	66	−1
250	73	+3	72	+5	.....	.....	72	−3	76	−3	62	−2
500	71	+7	63	+2	77	−2	69	−2	75	0	59	−2
750	69	+9	57	−1	76	+4	67	0	70	0	57	−2
1,000	63	+8	55	−1	73	+7	60	−2	66	+1	56	−3
1,250	55	+5	54	0	71	+10	56	−1	65	+4	55	−3
1,500	49	+3	56	+4	71	+12	55	+1	67	+9	51	−5
2,000	44	+3	58	+9	67	+9	49	0	60	+7	47	−7
2,500	42	+2	57	+12	58	0	47	+1	66	+12	48	−5
3,000	40	0	58	+16	58	0	40	−2	74	+19	46	−7
3,500	42	+1	55	+16	50	−6	39	−1	79	+22	55	+1
4,000	44	+2	56	+15	45	−9	40	+2	79	+23	63	+1
4,500	.....	.....	57	+16	.....	.....	.....	.....	78	+23	73	+1

VAPOR PRESSURE (mb.)

Surface	4.67	−1.01	6.78	+0.03	1.26	−1.14	8.88	+0.02	2.57	−1.24	3.83	−0.33
250	4.63	−1.01	6.68	+0.01	.....	.....	8.38	−0.12	2.54	−1.19	3.56	−0.39
500	4.30	−0.76	6.09	−0.03	1.23	−1.12	7.54	−0.26	2.26	−1.05	3.26	−0.45
750	4.09	−0.51	5.72	−0.03	1.25	−0.95	7.04	−0.17	2.06	−0.97	3.08	−0.45
1,000	4.00	−0.20	5.36	−0.01	1.31	−0.84	6.22	−0.28	2.03	−0.76	2.84	−0.45
1,250	3.57	−0.21	4.90	0.00	1.35	−0.74	5.75	−0.08	2.02	−0.53	2.62	−0.44
1,500	3.12	−0.25	4.78	+0.36	1.36	−0.61	5.43	+0.20	2.01	−0.32	2.38	−0.47
2,000	2.53	−0.21	4.23	+0.61	1.24	−0.46	4.58	+0.40	1.71	−0.21	2.06	−0.38
2,500	2.04	−0.26	3.52	+0.74	0.98	−0.41	3.91	+0.54	1.80	+0.15	1.94	−0.16
3,000	1.65	−0.30	3.30	+1.11	0.84	−0.24	3.06	+0.40	1.70	+0.26	1.64	−0.15
3,500	1.56	−0.12	3.00	+1.33	0.69	−0.09	2.77	+0.65	1.66	+0.39	1.72	+0.11
4,000	1.45	+0.04	2.54	+1.12	0.64	+0.07	2.65	+0.91	1.60	+0.59	1.60	+0.11
4,500	.....	.....	2.09	+0.93	.....	.....	.....	.....	1.54	+0.71	1.55	+0.11

[1] Naval Air Station.

TABLE 2.—*Free-air resultant winds (m. p. s.) during January, 1929*

Altitude m. s. l.	Broken Arrow, Okla. (233 meters)				Due West, S. C. (217 meters)				Ellendale, N. Dak. (444 meters)				Groesbeck, Tex. (141 meters)				Royal Center, Ind. (225 meters)				Washington, D. C. (34 meters)			
	Mean		Normal		Mean		Normal		Mean		Normal		Mean		Normal		Mean		Normal		Mean		Normal	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
Meters	°		°		°		°		°		°		°		°		°		°		°		°	
Surface	N.49 W.	0.8	S.51 W.	1.0	N.82 W.	0.5	N.81 W.	1.3	N.50 W.	3.1	N.63 W.	3.1	S.25 W.	2.4	S.68 W.	0.5	S.79 W.	2.6	S.58 W.	2.2	N.64 W.	1.2	N.44 W.	1.7
250	N.47 W.	0.8	S.47 W.	1.2	N.85 W.	0.6	N.84 W.	1.5					S.29 W.	1.9	S.69 W.	0.8	S.74 W.	2.4	S.54 W.	2.6	N.73 W.	3.6	N.71 W.	3.7
500	S.58 W.	1.4	S.39 W.	2.3	S.77 W.	2.7	S.86 W.	3.1	N.52 W.	3.3	N.67 W.	3.6	S.45 W.	3.3	S.54 W.	2.1	S.68 W.	3.6	S.61 W.	5.2	N.72 W.	7.4	N.73 W.	3.7
750	S.53 W.	2.3	S.46 W.	3.2	S.89 W.	4.4	S.85 W.	4.7	N.52 W.	4.6	N.65 W.	5.7	S.44 W.	4.7	S.56 W.	3.1	S.72 W.	5.3	S.69 W.	7.0	N.72 W.	10.0	N.72 W.	7.7
1,000	S.61 W.	2.9	S.61 W.	3.8	S.82 W.	5.8	S.83 W.	6.0	N.57 W.	5.5	N.63 W.	6.7	S.54 W.	5.6	S.60 W.	3.9	S.70 W.	5.8	S.77 W.	7.9	N.69 W.	10.9	N.71 W.	8.4
1,250	S.79 W.	3.7	S.73 W.	4.4	S.86 W.	6.7	S.88 W.	8.0	N.61 W.	6.3	N.62 W.	7.8	S.63 W.	6.3	S.67 W.	4.9	S.69 W.	6.9	S.82W.	8.9				
1,500	N.89 W.	5.0	S.77 W.	5.5	S.78 W.	8.1	S.87 W.	10.1	N.61 W.	7.4	N.63 W.	8.4	S.70 W.	7.2	S.72 W.	6.0	W.	9.4	S.85 W.	10.3	N.67 W.	11.6	N.70 W.	11.0
2,000	N.82 W.	7.3	S.85 W.	7.5	S.83 W.	11.3	S.89 W.	12.5	N.58 W.	10.2	N.63 W.	11.0	S.80 W.	8.4	S.79 W.	7.2	N.74 W.	11.4	S.87 W.	12.1	N.66 W.	13.5	N.72 W.	11.1
2,500	N.87 W.	9.1	W.	9.0	S.77 W.	14.3	S.88 W.	14.9	N.63 W.	12.1	N.65 W.	13.0	N.80 W.	9.2	S.82 W.	8.5	N.63 W.	8.9	N.89 W.	13.4	N.71 W.	15.4	N.79 W.	15.6
3,000	N.84 W.	11.7	N.87 W.	10.3	S.70 W.	13.0	S.87 W.	15.9	N.61 W.	15.4	N.65 W.	14.6	S.88 W.	10.0	S.82 W.	9.9	S.45 W.	15.0	W.	14.2	N.67 W.	18.4	N.80 W.	15.5
3,500	N.79 W.	11.2	N.84 W.	10.9	S.63 W.	14.8	S.84 W.	16.1	N.75 W.	12.4	N.66 W.	15.4	S.83 W.	8.9	S.84 W.	10.9	S.45 W.	18.0	S.84 W.	13.4	N.68 W.	16.5	N.77 W.	17.0
4,000	S.76 W.	10.3	N.84 W.	10.8	S.69 W.	17.1	S.84 W.	15.6	S.68 W.	19.0	N.63 W.	16.7	S.78 W.	14.3	S.75 W.	12.1								
4,500					S.45 W.	20.0	N.87 W.	8.4					S.78 W.	14.7	S.75 W.	14.1								

THE WEATHER IN THE UNITED STATES

THE WEATHER ELEMENTS

By P. C. DAY

GENERAL CONDITIONS

Unlike the first month of the winter of 1928–29, January was a notably cold and disagreeable month over nearly all northern districts, with deep snows from the upper Mississippi Valley eastward to and including the Great Lakes. In other districts, however, normal winter conditions prevailed as a rule.

PRESSURE AND WINDS

The month was ushered in with a cold wave over the Great Plains and a cyclone of wide proportions centered near the Great Lakes, and rain or snow had fallen during the perceding 24 hours over a wide area from the Great Plains eastward nearly to the Atlantic coast, heavy snow being reported at points in the lower Missouri Valley and over other near-by areas. This storm moved rapidly to the lower St. Lawrence Valley by the morning of the 2d, the snow continuing in portions of the Great Lakes region, but precipitation had generally ended to the southward and fair weather prevailed on the 3d over most districts.

A cyclone that had developed over the Southwest without material precipitation was centered over the lower Missouri Valley by the morning of the 4th and widespread precipitation had covered the Great Plains and eastward to the Mississippi Valley, snow occurring over the districts to northward of the center and some heavy rains to the southward. During the following day precipitation extended eastward to the Atlantic coast, snow continuing over northern districts and rain over the more eastern and southern, followed by a wide area of cold that carried freezing temperatures to or near the Gulf coast within a few days. During this period warmer weather overspread the western districts and, with the passage of the precipitation area into the Atlantic, fair weather prevailed over nearly all districts, a change to colder following quickly over the central valleys and this again by warmer, changes amounting from 20° to 50° in 24 hours being reported from points in the upper Mississippi Valley and other areas.

By the 9th another cyclone had developed over the southern plains and within the following 24 hours the storm center had moved to the northward of the Great Lakes and precipitation, mostly rains, had extended to all central and eastern districts, except the extreme Southeast. At the same time high pressure dominated the plateau region and by the end of the first decade the weather had cleared over most districts except along the northern border where clouds and local precipitation, mostly snow, persisted for several days.

About the 17th stormy conditions had developed in the central valleys and precipitation was more or less general from the Mississippi Valley eastward; similar conditions continued for several days, during which time widespread snows occurred over the western mountains and general rains occurred over many eastern districts. By the end of the second decade fair and cold weather had overspread most northern districts, continuing with some interruption during the remainder of the month, more or less rain or snow falling at intervals during the period, but particularly about the 25th, when a cyclone advanced from southern Texas to the Great Lakes, becoming severe as it approached the latter area and attended by rain or snow and high winds. During this period cold weather continued in the far Northwest.

Anticyclonic conditions existed during much of the latter half of the month over the far Northwest and also in the Missouri and upper Mississippi Valleys.

General high winds occurred over portions of the upper Mississippi Valley and Great Lakes region on several dates in connection with cyclones passing over those regions, causing much drifting of snow, and resulting in inconvenience and delay to transportation, but these caused no important damage to property.

Severe local storms assuming tornadic force occurred locally in Texas on the 4th and in Kentucky, Indiana, Illinois, and Missouri on the 18th. A full account of the principal destructive wind storms of the month appears as usual at the end of this section, and the details of wind direction and barometric pressure data are shown on the usual charts.

TEMPERATURE

Cold weather prevailed at the beginning of the month over the central valleys, but there was some warming up generally as the week advanced over most central and eastern districts, followed quickly by sharp changes to colder and again to warmer toward the end of the week, the average temperature for the period being moderately below normal over the greater part of the country, and

distinctly below from the Gulf States northward to Canada.

The second week had some marked temperature changes in the northern and central districts from the Rocky Mountains eastward and the weekly means were again below normal from the Ohio and middle Mississippi Valley northward, elsewhere they did not depart greatly from the normal, being generally well above, however, from Texas northwestward to the Canadian border.

The week ended January 22d averaged much colder than normal over the northern districts from the upper Lakes westward to the Pacific coast and over the far Southwest, the week being particularly cold over the upper Missouri Valley and the far Northwest. This week, as a whole, was distinctly warmer over the Gulf States and near-by areas. The last decade of the month was bitterly cold over the northwestern districts, the averages for the week ranging from 15° to 30° below the normal for the period, from the upper Mississippi Valley westward to the plains of Washington and Oregon, and cold weather existed throughout the remaining sections save in the southern portions from Texas eastward to the south Atlantic coast and over portions of the southern drainage area of the Ohio. In portions of the upper Missouri Valley and near-by States this period was one of the coldest of record and in many sections of this area the highest temperatures during the period did not rise above zero and the lowest values ranged from 30° to more than 50° below zero.

For the month, as a whole, average temperatures were below normal over all parts of the country save the southern tier of States and along the Atlantic coast northward to New England. At numerous points along the northern border from Lake Superior westward it was among the coldest Januarys of record.

The coldest periods of the month were mainly toward the end, though over the Gulf and South Atlantic States they occurred mainly about the 3d and from the Ohio Valley and Lake region eastward near the 15th. The lowest temperature reported, −56°, was observed at a point in Montana.

Some unusually high January temperatures occurred in Ohio on the 18th and 19th and in Florida on the 21st. Maximum day temperatures did not rise above 50° at any time during the month in the upper Lake region and in some States to the westward.

PRECIPITATION

The monthly amounts of precipitation were below the normal over all the far Western States as was the case during the preceding month, and also in November over the northern section of that area. The deficiency was particularly large in the coastal districts, where many stations had less than one-third the usual fall. Precipitation was likewise less than normal over most of the Atlantic Coast States and in the Appalachian Mountain region and locally in the middle and southern Rocky Mountain and Plains States.

Precipitation was above normal over nearly all northern and central districts from the mountains of Idaho and Utah eastward to the Ohio Valley and Great Lakes region. In portions of the upper Mississippi Valley and in the vicinity of the upper Lakes the month was in many instances the wettest January of record. Much cloudy, rainy, or snowy weather prevailed, and with glaze that formed on several occasions, caused ice coatings that interfered greatly with traffic and made travel dangerous.

SNOWFALL

Over the Northern States from the Dakotas eastward to and including the Great Lakes the monthly snowfall was unusually heavy and in many sections of this area, particularly in the upper Mississippi Valley and the near-by portions of adjoining States, the snowfall was the greatest ever experienced in any January, and locally the greatest in any month of record. Over other sections of the country where snow is usually heavy to moderate, notably in New England and near-by districts, the January snowfall was mainly less than normal and this was the case likewise in the southern districts where show usually falls to appreciable depths.

In the western mountains snowfall was normal or above throughout the Rocky Mountain region and generally somewhat above in the mountains of the Plateau. On the higher elevations of Washington and Oregon the snowfall was mainly satisfactory, but at the high elevations of the Sierra Nevada in California and Nevada the stored snow was materially less than is usually accumulated by the end of January.

Considerable amounts of glaze formed in the upper Mississippi Valley and Lake region, making travel unsafe locally for considerable periods, and numerous accidents occurred.

RELATIVE HUMIDITY

The average relative humidity was generally above normal over most districts from the Great Lakes westward and southwestward to the Pacific coast, but from the southern portions of Arizona and New Mexico eastward and northeastward to the Atlantic coast the average humidity was mainly less than normal, a few exceptions being noted near the south Atlantic coast and in the west Gulf coast sections.

SEVERE LOCAL STORMS, JANUARY, 1929

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of path, yards [1]	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Sealy, Tex.	4	6:15 p. m.	100		$10,000	Tornado	Buildings damaged over path 10 miles long; 5 persons injured.	Official, U. S. Weather Bureau.
Bay City, Tex. (5 miles south of).	4	8 p. m.	150	5		do	Everything in path demolished; 14 persons injured.	Do.
Jeffersonville, Vt.	5	P. m.				Wind	A number of barns demolished; some cattle killed; roofs blown off.	Burlington Free Press (Vt.)
Wilkes-Barre, Pa., and vicinity.	5	P. m.				Wind and rain	Considerable property damaged; traffic congested; many small fires.	Official, U. S. Weather Bureau.
Buffalo, N. Y.	6			1		Severe wind	Considerable damage to buildings, street signs, etc.; minor damage in other parts of State.	Do.
Sealy, Tex. (near)	10	3:20 a. m.	4 mi.			Hail	Considerable damage over path 6 miles long	Do.
Scott County, Mo., through southern Illinois and southwestern Indiana.	18			6		Series of tornadoes and high winds.	Many barns demolished; residences damaged; wire systems impaired; a number of school children injured.	Official, U. S. Weather Bureau; Evansville Journal (Ind.).
Kentucky	18	P. m.		4	1,250,000	Tornadic winds	Widespread damage throughout State; hundreds of barns and contents destroyed; homes, business houses, wire systems, and timber damaged; 5 persons injured.	Official, U. S. Weather Bureau.
Shelby, Miss.	18			1		High wind	Considerable property damage	Do.
Buffalo, N. Y.	19	P. m.		1		do	Considerable damage to plate-glass windows, signs, etc.	Do.
Wisconsin (east-central counties).	22					do	Overhead wires and small buildings damaged; smokestack blown down; traffic impeded by snow.	Do.
Parkersburg, W. Va.	25					do	Overhead wires damaged	Do.

[1] "Mi." signifies miles instead of yards.

RIVERS AND FLOODS

By R. E. SPENCER

General rains beginning on the 16th and continuing, with high temperatures, until late evening of the 19th over the region east of the Mississippi River and north of the Ohio, resulted in unimportant floods in the lower Great Lakes drainage and in moderate rises in several of the northern tributaries of the Ohio. Of the latter only those in the Allegheny River and the Wabash-White system were considerable, and even these did comparatively little damage. Along the Allegheny, where the presence of ice resulted in two gorges of minor importance between Franklin and Parkers Landing, unavoidable losses amounted to $5,000, while at Lock No. 7 the safe removal of $50,000 worth of machinery was effected through the timeliness of the Weather Bureau flood warnings. Losses in the more sustained Wabash-White rise reached $101,500, of which $40,800 was in tangible property (bridges, highways, etc.) and $49,000 in farm property. In addition to a considerable saving in livestock for which no estimate could be obtained, property valued at $19,000 was saved along the Wabash-White through the flood warnings.

A second period of substantial rains extending from the Middle West States southward to the Gulf on the 23d–24th was followed by moderate rises in several streams in that section—notably in the Illinois, the lower Ohio, the White and Black of Arkansas, and the Sulphur of Texas.

On the Sulphur River the losses (combined with those of a somewhat lesser rise earlier in the month) amounted to $11,000, and the savings through flood warnings to $33,000. Reports from other districts report some inconvenience owing to flooded highways, but no material damage.

Losses in the Tombigbee River rise of the 31st amounted to $700.

[All dates in January except as otherwise specified]

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
EAST GULF DRAINAGE					
	Feet			*Feet*	
Tombigbee: Lock 4, Demopolis, Ala.	39	31	31	39.5	31
GREAT LAKES DRAINAGE					
Maumee: Fort Wayne, Ind.	15	19	20	15.7	19
		23	23	15.6	23
St. Joseph: Montpelier, Ohio	10	19	23	12.6	21
Sandusky:					
Upper Sandusky, Ohio	13	19	20	15.8	20
Tiffin, Ohio	7	19	21	8.1	21
MISSISSIPPI DRAINAGE					
Allegheny:					
Franklin, Pa.	15	20	20	15.0	20
Parkers Landing, Pa.	18	19	19	20.0	19
Lock 5, Freeport, Pa.	24	19	21	28.6	19
Lock 4, Natrona, Pa.	24	19	20	26.0	19
Ohio:					
Evansville, Ind.	35	26	Feb. 2	38.5	29
Dam 48, Cypress, Ind.	35	27	(1)	37.2	30
Shawneetown, Ill.	35	27	(1)	40.3	31
Shenango: Sharon, Pa.	9	20	21	12.0	20
Tuscarawas: Coshocton, Ohio	8	20	20	11.0	20
Walhonding: Walhonding, Ohio	8	18	20	12.0	19
Scioto:					
Larue, Ohio	11	25	27	13.3	26
Prospect, Ohio	10	20	21	12.1	20
Circleville, Ohio	10	20	21	14.5	20
Chillicothe, Ohio	16	21	22	17.0	21
Olentangy: Delaware, Ohio	9	19	19	9.6	19
Stillwater: Pleasant Hill, Ohio	13	19	19	13.3	19
Green: Lock No. 2, Rumsey, Ky.	34	29	31	34.7	30
Wabash:					
Lafayette, Ind.	13	19	25	16.6	20
Covington, Ind.	16	20	27	20.2	25
Terre Haute, Ind.	16	24	28	17.6	26
Vincennes, Ind.	14	25	(1)	15.8	28
Mount Carmel, Ill.	16	21	(1)	23.0	29, 30
White: Decker, Ind.	18	22	(1)	23.5	28–30
White, East Fork:					
Seymour, Ind.	10	19	27	13.3	26
Williams, Ind.	10	23	(1)	14.7	26
Shoals, Ind.	20	23	(1)	26.4	26
White, West Fork:					
Anderson, Ind.	12	20	20	12.6	20
Elliston, Ind.	19	19	29	24.0	23
Edwardsport, Ind.	15	20	(1)	19.0	24
Tennessee: Riverton, Ala.	33	28	29	33.9	29
Elk: Fayetteville, Tenn.	14	25	28	21.0	26

[1] Continued at end of month.

[All dates in January except as otherwise specified]

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
MISSISSIPPI DRAINAGE—continued					
Illinois:	*Feet*			*Feet*	
Morris, Ill.	13	23	24	13.6	23
Peru, Ill.	14	(2)	(1)	19.5	24, 25
Henry, Ill.	10	23	(1)	12.7	28
Peoria, Ill.	18	25	(1)	19.6	30
Havana, Ill.	14	(2)	2	14.7	Dec. 26
		6	(1)	16.8	31
Beardstown, Ill.	14	(2)	2	14.8	12/27, 28
		23	(1)	17.5	29–31
Pearl, Ill.	12	25	(1)	13.3	30, 31
St. Francis: St. Francis, Ark.	17	20	(1)	24.5	30
Arkansas: Yancopin, Ark.	29	28	(1)	30.5	31
Petit Jean: Danville, Ark.	20	7	7	20.1	7
		25	27	23.3	26
White:					
Calico Rock, Ark.	18	25	26	26.7	25
Batesville, Ark.	23	25	28	31.7	25
Newport, Ark.	26	26	(1)	29.0	29
Georgetown, Ark.	22	29	(1)	24.4	31
Black:					
Williamsville, Mo.	11	26	26	12.3	26
Poplar Bluff, Mo.	14	25	28	16.5	27
Corning, Ark.	11	19	(1)	14.1	31
Black Rock, Ark.	14	25	(1)	24.6	26
Cache: Patterson, Ark.	9	27	(1)	9.6	31
Sulphur:					
Ringo Crossing, Tex.	20	6	9	26.5	7
		25	29	28.4	28
Finley, Tex.	24	9	15	26.2	18
		28	(1)	26.7	29
Ouachita:					
Arkadelphia, Ark.	12	26	27	14.1	26
Camden, Ark.	30	29	(1)	31.7	30
WEST GULF DRAINAGE					
Trinity:					
Dallas, Tex.	25	25	25	27.1	25
Trinidad, Tex.	28	28	(1)	29.8	30
Guadalupe: Victoria, Tex.	16	5	6	25.9	5

[1] Continued at end of month. [2] Continued from last month.

MEAN LAKE LEVELS

NOTE.—The printing of the table Mean Lake Levels, appearing since 1914 in this space, is suspended until further notice. Readers of the REVIEW who use the data, if there be such, are asked to communicate with the editor giving their reasons for its continuance.—*Editor.*

EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS, JANUARY, 1929

By J. B. KINCER

General summary.—During the first decade the passage of a storm across the country seriously interfered with outdoor operations and was rather hard on livestock in some western sections. A generous snow cover was deposited by this storm in several interior districts and furnished ample protection against the cold which followed. Rains relieved the droughty conditions in most Southeastern States, though southern Florida remained dry. Moderate freezes occurred in the southern trucking sections of that State, but no serious damage was reported. Lower temperatures in the far Southwest were beneficial for citrus fruits and no damaging frosts occurred in south Pacific areas. Increased feeding of livestock was necessary in parts of the great western grazing area.

During the second decade the weather was again rather unfavorable for seasonal work on farms. Frequent rains in the South prevented plowing and other field operations, but there was still a deficiency of precipitation in southern Florida. The temperatures in this section were mostly favorable, although the mildness caused some apprehension as to the possible premature forcing of peach bloom, especially in Georgia. In the Northwest and most Rocky Mountain sections the period was cold, stormy, and rather hard on livestock, though the snow was beneficial for grain fields. Rain was needed in the Southwest, especially in western Texas and New Mexico, but in other sections there were some helpful falls. Much of the interior of the country was bare of snow.

During the last decade much the coldest weather of the season prevailed in many sections from the central and northern Mississippi Valley westward, preventing seasonal outside operations and causing suffering among livestock. The January snowfall was unusually heavy in the western Lake region and extreme upper Mississippi Valley, with all previous records for the month broken in some places. The southeastern part of the country again experienced unusually mild weather for the season, with peach buds reported swelling in the Fort Valley district of Georgia and early varieties of fruit beginning to bloom in extreme southern Alabama, but the reaction to colder at the close of the month was beneficial in retarding premature development. Frequent rains in the South prevented much field work and very little preparation for spring planting could be made. Moisture was still needed in southern Florida and much of the Southwest.

Small grains.—During the first decade a light to generous snowfall preceded the cold weather over much of the winter wheat belt, which afforded a protection against the severe weather. In Nebraska the snow drifted badly and left some sections uncovered, while in Kansas the ground was bare in the northwestern part and wheat was frozen down. Conditions were also rather precarious in those parts of the Ohio Valley insufficiently covered and there was a lack of covering in the middle Atlantic area. In Montana and the Rocky Mountain districts most wheat fields had some protection and in the Pacific Northwest there was an ample covering when the coldest weather occurred; low temperatures retarded growth in the Southern States.

The weather was rather unfavorable for winter wheat during the second decade in many sections of the interior, though no extensive or widespread damage was reported. In the more eastern portions of the belt abnormally high temperatures caused a rapid disappearance of the snow cover and the ground was generally bare in much of the Ohio Valley; there was some ice in parts of Illinois and heavy rains caused local flooding in both Indiana and Ohio. From the northern portions of Illinois and Missouri northward wheat fields were generally well protected and also in the northern Great Plains, the Pacific Northwest, and most Rocky Mountain sections. In the main western belt the ground was bare with wheat frozen to the ground in western Kansas and some heaving in the southeast, but apparently without serious injury. In Oklahoma the crop was making slow growth, but in the Southern States winter grains made good progress under favorable conditions.

During the last decade the weather was mostly unfavorable for winter wheat, except in the more northern portions where there was a good snow cover. There was much ice in parts of Illinois and the northern third of Indiana, with a considerable cover in much of Missouri. In Kansas the ground continued bare in the western and southern portions, with the wheat frozen to the ground; most fields were still bare in Nebraska. Conditions were better in the far Northwest, and in the South the weather was largely favorable, but in the middle Atlantic area fields were mostly bare.

Miscellaneous crops.—There was some improvement in pastures in the Gulf section during the month, and an adequate protection for meadows prevailed in the more northern sections of the country. Considerable yard feeding was necessary in the northern Great Plains, with

some suffering from the stormy weather. Some lower range remained open in Wyoming, but the generally unfavorable weather caused shrinkage of livestock, especially during the first decade when crusted snow was reported. Low temperatures caused suffering in the central Rocky Mountain area, with some shrinkage noted, and additional snows necessitated more extensive feeding. Moisture was needed in New Mexico and western Texas, but rain or snow increased the water supply in Arizona, although causing some suffering to livestock. Deep snow was hard on livestock in Utah, especially during the last decade when it hindered feeding of isolated herds. Feeding was heavy during the month in Nevada and Idaho; the cold weather was unfavorable for the growth of grass in Pacific coast sections, but livestock did well.

Conditions were favorable for winter truck most of the month in the South, although there was some retardation by cold; the reaction to lower temperatures at the close prevented premature development of vegetation. Much truck was planted in the Carolinas and conditions favored work in Florida most of the month. Much new growth of citrus was reported in Florida, with some bloom toward the close of the month; navel orange, grapefruit, and lemon picking advanced in California, although there was some frost injury in the Imperial Valley and considerable firing was necessary during the last decade.

WEATHER OF THE ATLANTIC AND PACIFIC OCEANS

NORTH ATLANTIC OCEAN

By F. A. YOUNG

The weather over the North Atlantic during January was most unusual in many respects. The number of days with gales was equal to or above the normal over the greater part of the ocean, except for the region east of the twentieth meridian, where it was considerably below. Vessels in the trans-Atlantic route often encountered a series of heavy storms, lasting in some cases from six to eight days, while the storm area extended much farther south than usual, as in the region between the Azores and Bermudas gales were reported on from five to six days.

As shown in Table 1, the average pressure was much below the normal at Horta and above at land stations on the British Isles. An area of high pressure covered the coast of northern Europe for the first 14 days of the month. At Lerwick the average barometric reading for this period was 30.55 inches, with the lowest reading of 30.20 inches on the 1st. The average reading at this station for the last 17 days of the month was 29.99 inches or 0.29 inch above the monthly normal.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, 8 a. m. (seventy-fifth meridian). North Atlantic Ocean, January, 1929*

Stations	Average pressure	Departure [1]	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Julianehaab, Greenland	[2] 29.52	([3])	30.20	11th	28.55	21st.
Belle Isle, Newfoundland	29.48	−0.32	30.34	6th	28.34	21st.
Halifax, Nova Scotia	29.84	−0.16	30.78	5th	29.18	29th.
Nantucket	29.99	−0.10	30.70	5th	29.52	19th.
Hatteras	30.11	−0.02	30.52	3d	29.68	6th.
Key West	30.08	−0.01	30.22	14th	29.84	29th.
New Orleans	30.12	+0.01	30.48	2d	29.76	5th.
Cape Gracias, Nicaragua	29.91	−0.03	29.96	7th [4]	29.88	5th. [4]
Turks Island	30.13	+0.08	30.20	7th [4]	29.92	30th.
Bermuda	30.21	+0.08	30.52	5th [4]	29.66	29th.
Horta, Azores	29.80	−0.30	30.28	3d [4]	29.20	29th.
Lerwick, Shetland Islands	30.24	+0.54	30.90	11th	29.69	19th.
Valencia, Ireland	30.20	+0.30	30.69	13th	29.57	31st.
London	30.28	+0.28	30.78	8th	29.90	15th.

[1] From normals shown on Hydrographic Office Pilot Chart, based on observations at Greenwich mean noon, or 7 a. m., seventy-fifth meridian time.
[2] Average of 27 observations.
[3] No normal available.
[4] And on other dates.

The number of days with fog was much below the normal over the Grand Banks and northern steamer lanes, where fog was not reported on more than four days in any 5-degree square. In the western section of the Gulf of Mexico it was unusually prevalent, occurring on eight days, and on three days off the coast of Portugal.

During the first seven days of the month the middle and eastern sections of the steamer lanes were swept by a series of severe gales; on the 6th and 7th the storm area extended as far south as the Azores and to the eastward as far as the twentieth meridian. On the 8th moderate conditions prevailed generally, with the exception of the disturbance near the Azores, which by that time had moderated considerably.

On the 10th a severe disturbance of limited extent was central near 38° N., 37° W., while strong southerly gales also prevailed along the American coast between Hatteras and New York. By the 11th the southern LOW had decreased in intensity although northwest gales were still encountered by vessels near 35° N., 40° W., and southwesterly winds of force 7 to 10 in the region between the Bermudas and Newfoundland.

The next storm occurred on the 14th and was central near Sydney, Nova Scotia; this was of limited extent, although whole gales prevailed between the fortieth parallel and Newfoundland, while moderate weather was the rule over the remainder of the ocean.

From the 16th to the 19th the middle section of the steamer lanes was swept by moderate to strong gales, and on the latter date southwesterly winds of force 7 to 8 occurred west of the sixty-fifth meridian, between the thirty-fifth parallel and Nova Scotia.

Charts VIII to XIII cover the period from the 20th to 25th inclusive, and give an idea of the exceptionally stormy conditions that prevailed over the western and middle sections of the steamer lanes. It was on the evening of the 23d that the crew of the Italian S. S. *Florida* was rescued by a boat crew from the American S. S. *America*, Capt. George Fried. The observer on board the *America*, Mr. John Hultman, rendered a most interesting special report of the weather conditions experienced by his ship from 8 a. m. on the 20th to midnight on the 24th. Observations were taken every two hours until noon of the 21st, and every four hours during the remainder of the period. The force of the wind varied from 7 to 11 with the exception of a lull to force 3 in the early morning of the 21st, and again to force 4 at 4 p. m. on the 23d. The lowest barometer was 28.58 inches at 6 a. m. on the 21st, in 44° 22′ N., 51° 12′ W., and the highest force of wind, west 11, from 10 a. m. to 2 p. m. on the 20th, and again from 4 p. m. on the 21st to 8 a. m. on the 22d. At 8 p. m. on the 23d, near the time of rescue, the ship was in 40° 30′ N., 57° 30′ W., wind NW. 9, barometer 28.99; raining.

From the 26th until the end of the month, heavy weather continued in southern waters, the storm area on several days extending as far south as the thirtieth parallel, while during part of this period moderate to strong gales also prevailed along the American coast.

On the 30th and 31st southerly and westerly winds of force 7 and 8 were reported by vessels between the twentieth meridian and French coast.

OCEAN GALES AND STORMS, JANUARY, 1929

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN			° ′	° ′				*Inches*					
Pennsylvania, Dan. S. S.	Belfast	Philadelphia	48 55 N.	37 50 W.	Jan. 1	4 a., 1	Jan. 2	29.40	WNW.	WNW., 10	NNW.	—, 10	WNW.–NNW.
Quaker City, Am. S. S.	Middlesbrough.	do	36 51 N.	56 48 W.	2	Noon, 2	2	30.26	SW.	SW., 7	NW.	—, 11	
Caroline, Fr. S. S.	Galveston	Havre	49 08 N.	21 36 W.	1	5 a., 2	2	29.87	S.	S., 8	S.	S., 9	Steady.
West Nosska, Am. S. S.	Liverpool	Baltimore	35 06 N.	38 39 W.	2	4 a., 3	3	30.27	S.	SSW., 8	NW.	SSW., 8	S.–NW.
West Durfee, Am. S. S.	Galveston	Liverpool	27 00 N.	89 32 W.	4	2 p., 4	5	29.88	ESE.	ESE., 8	SSW.	ESE., 8	
Saguache, Am. S. S.	Gothenberg	Portland, Me.	48 35 N.	42 21 W.	3	2 p., 5	6	29.25	S.	WSW.	NW.	—, 11	WSW.–NW.
West Cobalt, Am. S. S.	New Orleans	Liverpool	39 00 N.	67 30 W.	5	9 p., 6	6	29.68	SSE.	SSW., 6	W.	SSW., 10	S.–W.
Trimountain, Am. S. S.	English Channel.	Galveston	41 00 N.	29 30 W.	6	9 a., 6	6	29.19	SSE.	NW.	NW.	NW., 11	
President Garfield, Am. S. S.	Gibraltar	New York	41 55 N.	60 55 W.	6	Noon, 7	7	29.55	S.	SSW., 10	W.	SSW., 10	S.–SW.–W.
General Gassouin, Fr. M. S.	Rouen	do	35 00 N.	38 00 W.	9	9 a., 10	11	29.37	SW.	W., 8	N.	—, 10	SW.–NW.
Sabine Sun, Am. S. S.	Marcus Hook	Baytown	28 12 N.	91 52 W.	11	8 a., 11	12	29.96	NNE.	NNE., 4	N.	N., 9	NNE.–N.
Minnekahda, Am. S. S.	Boulogne	New York	40 04 N.	58 20 W.	12	6 p., 12	12	29.27	S.	S., 9	W.	S., 9	S.–W.
Patagonier, Belg. S. S.	Antwerp	do	46 32 N.	54 03 W.	12	1 a., 13	13	29.52	SSE.	SSW., 10	SW.	SSW., 10	SSE.–S.–SSW.
Berlin, Ger. S. S.	Bremerhaven	do	46 54 N.	38 14 W.	15	10 a., 15	17	29.66	W.	WNW.	WNW.	—, 10	Steady.
Albert Ballin, Ger. S. S.	Hamburg	do	46 56 N.	38 10 W.	16	9 a., 16	17	29.59	NW.	WSW., 10	WNW.	WSW., 10	WSW.–NW.
Maine, Dan. S. S.	Nordenham	Baltimore	53 27 N.	39 03 W.	16	Mdt., 17	18	28.90	NW.	WNW.	WNW.	—, 11	NNW.–WNW.
Carlier, Belg. S. S.	New York	Antwerp	47 30 N.	37 41 W.	19	10 p., 19	21	29.33	S.	SE., 11	W.	SE., 11	NW.–W.–S.
Maine, Dan. S. S.	Nordenham	Baltimore	49 53 N.	47 34 W.	20	11 a., 20	27	28.29	S.	WSW.	NW.	—, 12	NW.–W.
Coeleda, Am. S. S.	Cardiff	do	43 45 N.	52 35 W.	16	2 a., 21	25	28.96		SW.	NW.	—, 11	SSE.–NW.
Maine, Br. S. S.	Antwerp	New York	48 30 N.	40 30 W.	20	8 p., 21	22	27.57	W.	NW., 12	NW.	NW., 12	Steady.
München, Ger. S. S.	New York	Cobh	44 32 N.	44 42 W.	19	8 a., 21	21	28.39	W.	WSW., 10		WSW., 11	SW.–WSW.
Mississippi, Br. S. S.	London	Boston	42 50 N.	54 23 W.	21	8 a., 22	23	29.91	W.	W., 11	NW.	W., 11	
City of Flint, Am. S. S.	Hull	New York	59 24 N.	12 00 W.	22	4 a., 22	24	30.02	SE.	SE., 8	SE.	—, 11	Steady.
Minnetonka, Br. S. S.	London	do	44 54 N.	45 08 W.	24	9 p., 24	26	28.33	SE.	N., 8	NNW.	N., 10	SE.–N.
Sarcoxie, Am. S. S.	New York	Havre	40 05 N.	45 51 W.	22	Mdt., 25	26	28.86	W.	NW., 6	Var.	NW., 10	Steady.
American Press, Am. S. S.	Newcastle	New Orleans	36 55 N.	33 15 W.	24	3 a., 26	26	28.90	SW.	SSE., 7	SSE.	WSW., 10	S.–WSW.
Arkansas, Dan. S. S.	Antwerp	Savannah	34 15 N.	49 30 W.	27	8 a., 27	29	29.36	WNW.	WNW., 11		WNW., 11	Steady.
Westerner, Am. S. S.	Liverpool	Norfolk	41 50 N.	35 00 W.	25	5 a., 28	30	28.87	SE.	S., 7	W.	NNW., 10	SW.–WNW.
Incemore, Br. S. S.	do	St. Johns, N.F.	52 25 N.	38 12 W.	28	Noon, 29	28	29.05	E.	E., 10	E.	E., 11	Steady.
Lorain, Am. S. S.	Hamburg	Philadelphia	47 00 N.	18 00 W.	29	8 a., 31	31	29.33	SSW.	SW., 7	W.	S., 9	SW.–W.
NORTH PACIFIC OCEAN													
Golden Dragon, Am. S. S.	Hong Kong	San Francisco	30 22 N.	141 07 E.	Jan. 1	Jan. 1	Jan. 4	29.62	WNW.	WNW., 6	WNW.	WNW., 9	Steady.
Edenton, Am. S. S.	Manila	San Pedro	40 53 N.	170 51 W.	Dec. 31	Dec. 31	1	28.85	ESE.	WNW., 10	W.	WNW., 12	
Dalblair, Br. S. S.	Vancouver	Shanghai	45 36 N.	155 21 E.	31	Jan. 3	4	28.44	N.	N., 6	NNW.	ENE., 9	
Iowa, Am. S. S.	Portland	Yokohama	46 06 N.	156 15 E.	30	4 p., 31	3	28.20	ESE.	NE., —	SSE.	E., 10	ESE.–E.–N.
Buenos Aires, Swed. M. S.	San Francisco	Panama	15 25 N.	96 46 W.	Jan. 1	Noon, 1	1	30.00	NE.	NE., 5	NW.	N., 8	
New York, Am. S. S.	Hong Kong	San Francisco	40 30 N.	152 00 E.	1	11 p., 1	2	28.78	SSE.	SSW., —	SW.	ESE., 10	ESE.–SW.
Tokiwa Maru, Jap. S. S.	Yokohama	Victoria	42 55 N.	158 25 E.	1	3 p., 2	2	28.53	ESE.	S., 5	WSW.	—, 9	SSE.–WSW.
Arabia Maru, Jap. S. S.	Victoria	Yokohama	42 00 N.	148 10 E.	1	2 p., 2	3	28.20	E.	SSW., 5	NW.	NW., 10	8 pts.
President Van Buren, Am. S. S.	Honolulu	Kobe	33 50 N.	144 50 E.	1	8 p., 1	3	29.24	SW.	W., 10	NNW.	W., 10	SW.–W.–NNW.
Hakushika Maru, Jap. S. S.	Miike	Victoria	46 18 N.	166 21 E.	2	6 a., 3	3	28.53	E.	S., 4	SSE.	E., 10	
Bokuyo, Maru, Jap. S. S.	Valparaiso	Los Angeles	13 55 N.	95 23 W.	6	—, 6	6	29.88	NNW.	N., 10	ENE.	N., 10	NNW.–ENE.
Atlantic, Am. S. S.	New York	Colon	14 50 N.	94 00 W.	6	4 a., 6	7	30.02	N.	N., 10	NNE.	N., 10	
Tamaha, Br. S. S.	Yokohama	San Francisco	40 30 N.	154 48 W.	6	2 a., 7	7	29.39	SE.	S., 9	S.	S., 9	SE.–S.
President Grant, Am. S. S.	Seattle	Yokohama	44 32 N.	156 56 E.	7	Mdt., 6	9	28.94	SE.	WSW., 9	NW.	WNW., 10	WSW.–WNW.
Golden Dragon, Am. S. S.	Hong Kong	San Francisco	40 10 N.	172 30 E.	9	4 a., 9	10	29.44	WNW.	WNW., 7	W.	W., 9	
Erviken, Nor. S. S.	Yokohama	Vancouver	46 35 N.	167 40 E.	9	Mdt., 8	10	29.02	SE.	SW., —	SW.	NW., 10	SE.–SW.–NW.
Golden Dragon, Am. S. S.	Hong Kong	San Francisco	43 05 N.	169 10 W.	11	10 a., 11	12	29.30	SE.	SE., 5	SE.	SE., 10	Steady.
Radnor, Am. S. S.	San Pedro	Kobe	29 00 N.	157 30 E.	11	2 p., 11	17	29.58	WNW.	WNW., —		N., 10	S.–NW.
Volunteer, Am. S. S.	Manila	Honolulu	24 55 N.	151 49 E.	13	6 a., 13	14	29.77	NW.	NW., 8	NNE.	NW., 9	NW.–NE.
Yogen Maru, Jap. S. S.	Miike	Vancouver	45 32 N.	178 52 E.	14	6 a., 15	15	28.40	N.	NW., 9	SSW.	NW., 9	2 pts.
Golden Wall, Am. S. S.	Hakodate	San Francisco	49 20 N.	172 00 W.	14		16	29.04	SSE.		W.	SSW., 10	NE.–S.–SW.
Bokuyo Maru, Jap. S. S.	Los Angeles	Honolulu	32 42 N.	125 51 W.	16	11 a., 16	17	29.86	NNW.	NW., —	N.	NW., 9	NNW.–N.
India Arrow, Am. S. S.	Wuhu, China	San Pedro	33 50 N.	169 40 E.	17	2 p., 17	17	29.44	SSW.	SSW., 9	NW.	N., 9	S.–W.–NW.
Tacoma, Am. S. S.	Englewood	Yokohama	45 45 N.	153 00 E.	17	3 a., 17	18	28.77	N.	N., 6	NW.	NNW., 10	N.–NW.
President Madison, Am. S. S.	San Francisco	Honolulu	36 19 N.	127 00 W.	19	8 a., 19	19	30.00	NNW.	NNW., 7	N.	NNW., 8	NNW.–N.
President Taft, Am. S. S.	Yokohama	Victoria	45 24 N.	161 45 E.	20	1 a., 21	21	28.82	ESE.	ESE., 8	SW.	SE., 11	ESE.–S.–SSW.
Silveroak, Am. M. S.	Surabaya	San Francisco	28 00 N.	151 00 E.	20	Noon, 22	22	30.10	SE.	SE., —	SE.	SE., 8	Steady.
President Cleveland, Am. S. S.	Seattle	Yokohama	47 04 N.	162 11 E.	21	8 a., 21	22	28.60	SSE.	W., 12	W.	W., 12	SSE.–W.
Maunawili, Am. S. S.	San Francisco	Honolulu	26 28 N.	147 32 W.	23	11 a., 23	23	29.65	SE.	SW., 7	WSW.	SE., 9	SE.–SW.
China Arrow, Am. S. S.	Hong Kong	San Pedro	37 22 N.	160 33 E.	28	—, 29	29	29.63	NW.	NW., 8	NW.	NW., 10	Steady.
Woyo Maru, Jap. S. S.	Muroran	Vancouver	46 17 N.	161 00 E.	28	2 p., 29	30	28.70	NW.	W., 9	SSW.	W., 10	WNW.–W.–SW.
Paris Maru, Jap. S. S.	Yokohama	do	46 05 N.	167 10 E.	28	Noon, 29	30	28.24	NW.	W., 12	SSW.	W., 12	WNW.–W.–WSW.
City of Honolulu, Am. S. S.	Honolulu	Wilmington	31 51 N.	129 26 W.	29	6 p., 30	31	29.63	S.	SE., —	SE.	SE., 8	S.–SE.
SOUTH PACIFIC OCEAN													
Golden Harvest, Am. S. S.	Lyttelton, N. Z.	Hawaiian Is.	24 05 S.	171 40 W.	22	11 p., 22	23	29.16	NE.	NNW., —	NW.	NW., 9	N.–NW.

NORTH PACIFIC OCEAN

By WILLIS E. HURD

A considerable change took place in the alinement of average atmospheric pressure over the North Pacific since December. The Aleutian cyclone moved westward [1] out of the Gulf of Alaska early in the month, and to some extent filled in, the center being situated in January over the middle Aleutians and the eastern part of Bering Sea, pressure at Dutch Harbor and St. Paul, 29.50 inches, both of which readings were below the normal. The period of the cyclone's greatest activity was from the 3d to the 8th. At Kodiak the average pressure was nearly 0.70 inch higher than in December, and 0.30 inch above the normal; hence the station this month, instead of being as usual within the cyclone's central area, was far on its eastern border. Low pressure on several occasions extended abnormally far southward in middle longitudes, but such activity was not attended by increased windiness in low latitudes.

The Pacific-California anticyclone was much disturbed on its western side by the incursions of cyclones from the west and north, but on its eastern side—from the coast to several hundred miles at sea—it was generally stable, and high pressures prevailed over most of the Gulf of Alaska and adjacent northeastern waters of the Pacific.

In Asiatic waters high pressure persisted for a good part of the month, and the northeast monsoon was accordingly brisk to strong on the China coast.

Pressure data for several island and mainland coast stations in west longitudes are given in the following table:

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level at indicated hours, North Pacific Ocean and adjacent waters, January, 1929*

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Point Barrow [1]	30.40		31.40	28th	29.68	16th.
Dutch Harbor [1]	29.50	−0.14	30.24	19th	28.72	5th.
St. Paul [1 2]	29.50	−0.19	30.10	19th [3]	28.62	4th.
Kodiak [1 2]	29.94	+0.30	30.50	19th	29.16	6th.
Midway Island [1]	29.92	−0.08	30.22	23d	29.42	25th.
Honolulu [4]	29.94	−0.06	30.11	31st	29.77	18th.
Juneau [4]	30.13	+0.25	30.67	27th	29.61	24th.
Tatoosh Island [4 5]	30.06	+0.12	30.50	9th	29.48	18th.
San Francisco [4 5]	30.08	−0.01	30.37	10th	29.66	16th.
San Diego [4 5]	30.03	−0.03	30.23	22d	29.66	16th.

[1] P. m. observations only.
[2] For 30 days.
[3] Also on 20th.
[4] A. m. and p. m. observations.
[5] Corrected to 24-hour mean.

As was said in the previous REVIEW, December, 1928, was the stormiest month in recent years on the North Pacific, dangerous gales blowing until the 31st, or with forces 11 to 12, according to complete reports, on 12 days of the month. Much abatement in storm energy followed in January. Although gales of force 8 or upward were of almost daily occurrence over the ocean as a whole, yet on only two days, according to present information, did they acquire full storm to hurricane severity. These days were the 21st and 29th, and the forces of 12 occurred within the area bounded by parallels 45° and 50° N., meridians 160° and 170° E., in connection with intense cyclones operating between Japan and the western Aleutians. In this general region the lowest pressures of the month, about 28.20 inches, were read on the 1st, 2d, and 29th. Continental cyclones of some severity were active over Japanese waters during early and middle days of the month, and caused strong to whole gales, with snow and sleet, especially on the 1st to 3d, over much of the northern and middle steamer routes west of the one hundred and sixtieth meridian of east longitude. The region of most frequently stormy January weather was bounded by latitudes 25° to 50° N., longitudes 145° to 170° E.; in its northeastern part, the sea was gale swept on fully 25 to 30 per cent of the days. In middle longitudes scattered gales occurred between the thirtieth and fiftieth parallels, being slightly most frequent along the northern route. Over the more settled region of the Pacific-California HIGH, and generally between the one hundred and sixtieth meridian of west longitude and the American coast, gales were rather infrequent and rarely exceeded nine in force.

Northers occurred in or near the Gulf of Tehuantepec on the 1st, 6th, and 29th. Those of the 6th attained the force of a whole gale.

At Honolulu the prevailing direction of the wind was from the northeast, blowing from that direction 40 per cent of the time; from the east, 36 per cent. The maximum velocity for the month was at the rate of 29 miles an hour from the northeast on the 22d. On this date and the 23d fresh to strong gales were encountered along the lower stretch of the California-Hawaiian route.

Fog occurrence changed but little from that of December, except that it was reported in January in east longitudes, where it was absent the previous month. Over a large area east of Japan it was observed in connection with sleet and snow during the prevalence of the cyclone of the 1st to 3d. Fog was reported on the 13th and 14th off the east coast of China, and on the 10th, 18th, and 20th in the Gulf of Tehuantepec. There were scattered occurrences off the California coast, where it was most widespread on the 1st, but the principal fog area lay along the upper steamer route in west longitudes, where it formed on about 20 per cent of the days.

[1] It is preferred to think of this apparent westward movement as being due to rising pressure immediately to the eastward of the usual geographic center of the Aleutian LOW and that the center of the low is thereby displaced to the westward. It is interesting to note that in this month the change to higher mean pressure was apparently world-wide being especially pronounced over northwestern Europe—*Editor.*

TYPHOONS AND DEPRESSIONS—SOUTHERN PART OF THE PHILIPPINES VISITED BY TWO DEPRESSIONS AT THE BEGINNING OF 1929

By Rev. José CORONAS, S. J.

[Weather Bureau, Manila, P. I.]

It happens very seldom that the Philippines are visited by more than one depression during the month of January. This year we had two, although, while in the Philippines, they were of no great intensity, and no damage was done, except by heavy rains and consequent floods. These floods were rather extraordinary in Butuan, Mindanao, during the second depression on January 23.

Owing to lack of sufficient observations from the Pacific east of Mindanao, we can not ascertain whether these two depressions were real typhoons before they struck the Philippines. The first of them was shown by our weather map of 6 a. m. January 5, about 300 miles to the south of Yap, near 5° latitude N., between 137° and 138° longitude E. It moved practically to W. on the 5th and 6th; to NW. and NNW. on the 7th and 8th; and inclined again westward on the 9th. On the 10th and 11th it was shown as a shallow depression over the southern Visayas moving SW. and WSW. It filled up on the 12th over the Sulu Sea.

The approximate positions of the center at 6 a. m. of the 5th, 7th, 9th and 10th were as follows:

January 5, 6 a. m., 137° 30′ longitude E., 5° 00′ latitude N.
January 7, 6 a. m., 132° 10′ longitude E., 5° 20′ latitude N.
January 9, 6 a. m., 129° 30′ longitude E., 9° 25′ latitude N.
January 10, 6 a. m., 125° 15′ longitude E., 10° 25′ latitude N.

The second depression appeared on the 17th and 18th far to the SSE. and S. of Yap, near 3° latitude N. It moved slowly to N. or NNW. on the 18th, and WNW. on the 19th. Then from the 20th to 24th it moved W. by N., traversing northeastern Mindanao near Surigao, and the southern part of the Visayas on the 23d. At the time we are writing these notes the center is still shown over the China Sea west of northern Palawan moving westward.

The approximate positions of the center at 6 a. m. of the 20th to 24th were:

January 20, 6 a. m., 136° 45′ longitude E., 7° 05′ latitude N.
January 21, 6 a. m., 134° 30′ longitude E., 7° 50′ latitude N.
January 22, 6 a. m., 130° 30′ longitude E., 8° 30′ latitude N.
January 23, 6 a. m., 124° 45′ longitude E., 9° 35′ latitude N.
January 24, 6 a. m., 121° 45′ longitude E., 10° 10′ latitude N.

CLIMATOLOGICAL TABLES

DESCRIPTION OF TABLES AND CHARTS

Table 1 gives the data ordinarily needed for climatological studies for about 180 Weather Bureau stations making simultaneous observations at 8 a. m. and 8 p. m. daily, seventh-fifth meridian time, and for about 34 others making only one observation. The altitudes of the instruments above ground are also given.

Beginning January 1, 1928, movement and velocity of the wind are printed as recorded by the 3-cup anemometer which has replaced the 4-cup pattern.

Table 2 gives, for about 37 stations of the Canadian Meteorological Service, the means of pressure and temperature, total precipitation, depth of snowfall and the respective departures from normal values except in the case of snowfall. The sea-level pressures have been computed according to the method described by Prof. F. H. Bigelow in the REVIEW of January, 1902, **30**: 13–16.

CHART I.—*Temperature departures.*—This chart presents the departures of the monthly mean surface temperatures from the monthly normals. The shaded portions of the chart indicate areas of positive departures and unshaded portions indicate areas of negative departures. Generalized lines connect places having approximately equal departures of like sign. This chart of monthly surface temperature departures in the United States was first published in the MONTHLY WEATHER REVIEW for July, 1909, but smaller charts appear in W. B. Bulletin U for 1873 to June, 1909, inclusive.

CHART II.—*Tracks of centers* of ANTICYCLONES; and CHART III.—*Tracks of centers* of CYCLONNES. The Roman numerals show the chronological order of the centers. The figures within the circles show the days of the month; the letters *a* and *p* indicate, respectively, the observations at 8 a. m. and 8 p. m., seventy-fifth meridian time. Within each circle is also given (Chart II), the last three figures of the highest barometric reading, or (Chart III) the lowest reading reported at or near the center at that time, in both cases as reduced to sea level and standard gravity. The inset map of Chart II shows the departure of monthly mean pressure from normal and the inset of Chart III shows the change in mean pressure from the preceding month.

CHART IV.—*Percentage of clear sky between sunrise and sunset.*—The average cloudiness at each Weather Bureau station is determined by numerous personal observations between sunrise and sunset. The difference between the observed cloudiness and 100 is assumed to represent the percentage of clear sky, and the values thus obtained are the basis of this chart. The chart does not relate to the nighttime.

CHART V.—*Total precipitation.*—The scales of shading with appropriate lines show the distribution of the monthly precipitation according to reports from both regular and cooperative observers. The inset on this chart shows the departure of the monthly totals from the corresponding normals.

CHART VI.—*Isobars at sea level, average surface temperatures, and prevailing wind directions.*—The pressures have been reduced to sea-level and standard gravity by the method described by Prof. Frank H. Bigelow in the REVIEW for January, 1902, 30:13–16. The pressures have also been reduced to the mean of the 24 hours by the application of a suitable correction to the mean of 8 a. m. and 8 p. m. readings at stations taking two observations daily, and to the 8 a. m. or the 8 p. m. observation, respectively, at stations taking but a single observation. The diurnal corrections so applied will be found in the Annual Report of the Chief of the Weather Bureau, 1900–1901, volume 2, Table 27, pages 140–164.

The sea-level temperatures are now omitted and average surface temperatures substituted. The isotherms can not be drawn in such detail as might be desired, for data from only the regular Weather Bureau stations are used.

The prevailing wind directions are determined from hourly observations at the great majority of the stations. A few stations determine their prevailing directions from the daily or twice-daily observations only.

CHART VII.—*Total snowfall.*—This is based on the reports from regular and cooperative observers and shows the depth in inches of the snowfall during the month. In general, the depth is shown by lines inclosing areas of equal snowfall, but in special cases figures also are given. This chart is published only when the snowfall is sufficiently extensive to justify its preparation. The inset of this chart, when included, shows the depth of snow on the ground at the end of the month.

CHARTS VIII, IX, etc.—*North Atlantic Weather maps of particular days.*

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, January, 1929 [1]

Section	Temperature								Precipitation					
			Monthly extremes								Greatest monthly		Least monthly	
	Section average	Departure from the normal	Station	Highest	Date	Station	Lowest	Date	Section average	Departure from the normal	Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	48.9	+3.0	Selma	84	21	St. Bernard	13	3	5.67	+0.61	Seven Hills	9.07	Milltown	2.80
Arizona	41.9	−1.7	2 stations	78	[2] 15	Pinedale	−20	24	0.93	−0.29	Bright Angel Ranger Station.	3.85	Parker	T.
Arkansas	39.4	−1.7	Hope	79	18	2 stations	2	[2] 2	5.08	+0.98	Dutton	8.00	Arkansas City	2.35
California	41.5	−2.7	Santa Ana	86	12	Helm Creek	−26	24	1.82	−3.64	Crescent City	9.24	Greenland Ranch	0.00
Colorado	22.3	−2.4	Canan City	75	14	Hermit	−32	27	0.70	−0.04	Cumbres	4.81	7 stations	0.00
Florida	62.7	+3.9	4 stations	89	[2] 22	Garniers	18	7	3.19	+0.41	Cottage Hill	7.81	Everglades	0.28
Georgia	50.3	+3.7	Quitman	85	24	3 stations	11	[2] 3	4.94	+0.70	Clayton	8.45	Hartwell	3.14
Idaho	16.1	−7.9	Deer Flat	54	2	Felt	−36	21	2.16	+0.06	Pine	5.91	Mud Lake	0.27
Illinois	21.7	−5.1	Cairo	70	18	Morrison	−24	15	3.98	+1.72	New Burnside	7.50	Warsaw	2.13
Indiana	25.0	−3.6	Rome	71	18	Wheatfield	−13	15	4.91	+1.86	Columbus	8.60	Covington	3.40
Iowa	10.2	−8.3	Sioux City	47	10	Decorah	−29	15	2.01	+0.99	Burlington	4.10	Onawa	0.40
Kansas	24.7	−5.2	Columbus	62	22	Lakin	−11	25	1.13	+0.46	Atchison	3.21	5 stations	T.
Kentucky	34.8	−0.6	2 stations	76	[2] 18	Scott	−6	14	4.54	+0.19	Paducah	7.90	Willow	2.16
Louisiana	53.3	+2.1	3 stations	83	[2] 22	2 stations	15	[2] 2	6.53	+1.80	Reserve	12.47	Winnsboro	2.25
Maryland-Delaware	32.9	+0.3	Washington, D. C.	69	19	Oakland, Md	−13	14	2.68	−0.69	Darlington, Md	4.22	Solomons, Md	1.22
Michigan	15.2	−4.6	Detroit	50	18	Humboldt	−32	16	3.05	+1.23	Houghton	6.33	St. Ignace	1.41
Minnesota	−2.7	−11.2	Worthington	46	8	3 stations	−41	[2] 13	1.25	+0.58	Winona	4.03	Alexandria	0.19
Mississippi	49.2	+2.1	2 stations	82	[2] 20	Port Gibson	13	7	5.24	+0.25	Bay St. Louis	8.88	Stoneville	2.31
Missouri	25.1	−5.4	Caruthersville	72	18	Unionville	−13	7	3.47	+1.43	Dexter	8.64	Warsaw	1.13
Montana	7.4	−10.8	3 stations	52	[2] 7	Hays	−56	28	0.91	−0.05	Adel	3.49	Valentine	0.15
Nebraska	16.4	−5.5	McCook	63	8	Gordon	−26	[2] 25	0.37	−0.18	Auburn	2.05	11 stations	T.
Nevada	28.7	−1.8	Las Vegas	79	[2] 14	Owyhee	−27	21	0.80	−0.18	Gold Creek	3.80	Lovelock	0.08
New England	22.3	−0.9	Pittsfield, Mass	65	6	Van Buren, Me	−36	[2] 15	3.61	+0.20	Colchester, Conn	6.22	Presque Isle, Me	1.23
New Jersey	30.7	+0.9	Hightstown	67	19	Culvers Lake	−4	14	3.39	−0.13	Charlotteburg	5.03	Cape May	1.92
New Mexico	32.5	−0.9	Deming	76	16	Dulce	−30	25	0.29	−0.26	Tierra Amarilla	2.41	21 stations	0.00
New York	22.8	+0.3	Cairo	68	19	Indian Lake	−29	5	3.29	+0.32	Lyons Falls	7.37	Harkness	0.89
North Carolina	42.8	+1.4	Newbern	79	19	2 stations	3	3	3.71	−0.23	Andrews	8.21	Moxley	1.32
North Dakota	−4.8	−9.7	Hettinger	42	8	2 stations	−42	[2] 25	0.63	+0.09	Dickinson	1.82	Tioga	T.
Ohio	25.8	−2.2	Peebles	76	18	McArthur	−15	14	4.36	+1.48	Sidney	7.30	Canfield	1.66
Oklahoma	35.9	−2.4	Antlers	73	19	3 stations	−5	[2] 24	2.09	+0.46	Smithville	6.75	Boise City	T.
Oregon	28.4	−5.1	Brookings	64	6	2 stations	−36	20	3.88	−0.71	Government Camp	15.10	Paisley	0.30
Pennsylvania	27.3	−0.5	Newell	73	19	Brookville	−20	16	3.37	+0.04	Driftwood	6.86	Towanda	1.12
South Carolina	46.7	+1.2	Garnett	82	23	2 stations	15	3	4.01	+0.46	Conway	7.16	Hogback Mountain	2.25
South Dakota	5.1	−10.8	Winner	53	8	Pollock	−39	29	0.94	+0.38	Mellette	2.95	Ardmore	0.09
Tennessee	39.9	+1.2	Newport	78	18	Rugby	8	[2] 3	4.80	+0.06	New River	7.77	Elizabethton	1.43
Texas	48.7	+0.2	2 stations	91	[2] 19	Romero	−3	25	2.11	+0.28	Lufkin	9.36	13 stations	0.00
Utah	22.9	−2.4	Kanab	68	13	Woodruff	−39	24	1.36	+0.13	Silver Lake	5.28	Bluff	0.10
Virginia	36.3	+0.4	Burkes Garden	76	19	Mount Weather	−1	14	2.51	−0.84	Speers Ferry	4.97	Hot Springs	1.16
Washington	23.1	−7.5	Bellingham (near)	58	2	Odessa	−33	30	2.65	−2.66	Paradise Inn	12.06	Oroville	0.12
West Virginia	31.4	−0.9	2 stations	75	[2] 18	Pickens	−19	14	2.92	−0.96	Bayard	7.48	Perry	1.05
Wisconsin	3.7	−10.3	Milwaukee	42	5	Blair	−43	15	2.61	+1.39	Blair	4.55	Coddington	0.82
Wyoming	12.7	−6.8	Powell	55	13	Riverside	−49	20	0.74	−0.06	Snake River	4.24	Diversion Dam	0.00
Alaska (December)	12.7	+9.5	Nikolski	56	27	Allakaket	−56	13	3.49	+1.19	Latouche	43.56	Shaktoolik	0.25
Hawaii	67.2	+0.5	Kaanapali	92	[2] 12	Volcano Observatory	43	10	8.77	−0.97	Puohakamoa	34.38	Eleele	0.66
Porto Rico	73.7	−0.2	San German	93	7	Guineo	46	29	3.82	+0.14	La Fe	21.63	3 stations	0.00

[1] For description of tables and charts, see page 36.

[2] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, January, 1929*

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	° *F.*	° *F.*	°*F.*		°*F.*	° *F.*		°*F.*	° *F.*	° *F.*	° *F.*	%	*In.*	*In.*		*Miles.*								*0–10*	*In.*	*In.*
New England							**25.0**	**+0.5**										**69**	**3.26**	**−0.2**										**5.5**		
Eastport	76	67	85	29.77	29.86	−0.14	21.0	+0.6	55	19	31	−9	15	12	35	19	12	70	3.58	−0.3	20	9,985	w.	38	s.	6	11	2	18	6.4	14.3	1.6
Greenville, Me	1,070	6	----	28.67	29.80	----	11.4	----	48	19	21	−17	14	2	37	----	----	----	3.35	----	15	----	nw.	----	----	----	9	7	15	----	23.8	----
Portland, Me	103	82	117	29.83	29.96	−.09	23.6	+1.2	56	19	32	−2	14	16	28	20	13	66	3.99	0.0	16	7,146	nw.	36	s.	6	15	5	11	4.7	16.1	1.6
Concord	289	70	79	29.62	29.93	−.10	20.8	−0.8	56	6	30	−16	16	12	41	----	----	----	3.00	0.0	11	5,096	nw.	24	nw.	24	14	9	8	4.6	28.1	4.9
Burlington	403	11	48	29.51	29.98	−.07	18.3	−0.5	55	19	27	−9	14	10	39	----	----	----	1.33	−0.4	16	9,063	nw.	40	s.	17	3	9	19	7.8	6.4	1.4
Northfield	876	12	60	28.99	29.99	−.06	15.1	−0.1	60	19	27	−20	5	4	47	13	10	81	2.42	+0.1	18	6,188	n.	36	sw.	19	2	11	18	7.5	17.2	4.5
Boston	125	115	188	29.83	29.97	−.08	29.6	+1.1	60	19	37	6	14	21	28	25	20	69	3.82	+0.2	11	8,345	w.	32	s.	16	13	8	10	5.0	13.5	2.1
Nantucket	12	14	90	29.96	29.97	−.07	31.6	+0.3	58	6	39	9	14	24	23	28	23	73	3.02	−0.8	13	11,957	nw.	47	w.	7	10	9	12	6.0	1.9	T.
Block Island	26	11	46	29.96	29.98	−.09	31.6	+0.6	57	6	38	10	14	25	25	28	23	70	3.21	−0.6	14	15,939	w.	56	sw.	7	15	9	7	4.9	5.1	0.0
Providence	160	215	251	29.81	30.00	−.06	28.4	+1.2	59	6	37	5	14	20	29	24	16	62	4.49	+0.8	11	9,810	nw.	46	n.	23	14	10	7	4.4	8.4	1.0
Hartford	159	122	----	29.85	30.03	−.04	27.2	+1.7	60	19	35	3	14	20	34	----	----	----	3.54	−0.4	11	----	nw.	----	----	----	16	5	10	4.5	10.7	2.3
New Haven	106	74	153	29.91	30.04	−.04	28.8	+0.6	59	19	36	5	14	21	28	25	18	64	3.49	−0.5	11	7,428	nw.	34	se.	6	15	8	8	4.5	5.6	1.0
Middle Atlantic States							**33.2**	**+1.2**										**69**	**2.54**	**−0.7**										**6.0**		
Albany	97	107	115	29.92	30.03	−.04	24.7	+1.6	62	19	33	−2	14	17	33	22	17	74	2.21	−0.2	15	5,668	nw.	26	s.	18	9	16	6	5.1	15.7	5.0
Binghamton	871	10	84	29.05	30.02	−.06	24.6	+0.5	62	19	33	1	14	16	35	----	----	----	1.87	−0.6	18	5,753	nw.	33	sw.	19	3	8	20	7.6	11.9	4.5
New York	314	414	454	29.70	30.06	−.04	32.1	+1.2	62	19	40	7	14	24	33	27	20	62	2.67	−1.0	11	14,724	nw.	60	s.	6	8	11	12	6.1	1.5	0.1
Bellefonte	1,050	5	36	28.91	30.06	----	24.8	----	59	18	34	−2	14	16	34	22	18	76	2.46	----	17	----	w.	----	----	----	5	9	17	7.0	6.5	3.9
Harrisburg	374	94	104	29.68	30.10	.00	30.4	+1.4	63	18	38	5	14	23	33	25	16	60	3.16	+0.1	12	5,381	nw.	37	s.	18	7	13	11	6.2	5.5	1.0
Philadelphia	114	123	367	29.96	30.10	−.01	34.2	+1.6	63	19	42	9	14	27	34	30	23	68	2.70	−0.6	9	9,852	nw.	45	s.	6	8	9	14	5.9	0.5	T.
Reading	325	81	98	29.71	30.08	----	31.2	----	62	19	39	8	14	24	36	27	23	75	3.57	0.0	12	5,799	nw.	28	se.	5	9	12	10	5.4	3.6	0.4
Scranton	805	111	119	29.16	30.06	−.03	27.2	+0.6	62	19	35	1	14	19	38	24	18	70	1.84	−1.2	12	5,987	sw.	33	sw.	7	4	8	19	7.5	2.3	1.2
Atlantic City	52	37	172	30.02	30.08	−.03	34.8	+2.3	64	19	43	8	14	27	27	31	25	70	3.02	−0.5	10	12,266	nw.	66	s.	6	11	8	12	5.6	0.1	0.0
Cape May	17	13	49	----	----	----	35.1	+1.0	62	19	42	12	14	28	28	31	26	72	1.92	----	10	----	nw.	----	----	----	10	8	13	----	~~0.2~~	~~0.0~~
Sandy Hook	22	10	55	30.03	30.06	----	31.7	----	60	19	38	9	14	26	28	28	23	71	3.80	−0.2	10	12,944	nw.	50	sw.	19	8	10	13	5.5	1.2	T.
Trenton	190	159	183	29.86	30.07	----	31.7	----	63	19	40	7	14	24	35	27	21	68	3.06	−0.2	10	8,285	nw.	36	nw.	13	10	9	12	5.8	0.8	0.1
Baltimore	123	100	215	29.96	30.10	−.02	35.4	+1.6	67	19	43	9	14	27	33	30	22	62	2.90	−0.6	10	7,552	sw.	40	nw.	6	11	6	14	5.5	0.7	T.
Washington	112	62	85	29.99	30.12	−.01	34.9	+1.5	69	19	44	8	14	26	34	30	21	61	2.16	−1.4	12	5,227	nw.	30	nw.	29	10	7	14	5.7	0.3	0.0
Cape Henry	18	8	54	30.07	30.09	----	42.2	----	71	18	50	22	14	35	32	38	33	72	3.07	−0.1	13	9,750	ne.	40	n.	29	11	7	13	5.7	0.2	0.2
Lynchburg	681	153	188	29.34	30.11	−.02	37.2	−0.3	67	19	46	14	14	28	31	32	25	63	2.38	−1.0	12	5,354	w.	34	nw.	6	11	7	13	5.7	0.9	T.
Norfolk	91	170	205	30.02	30.12	−.01	42.2	+1.6	70	18	50	19	14	34	33	37	32	72	1.81	−1.3	13	9,165	ne.	55	se.	5	11	7	13	5.7	0.3	0.3
Richmond	144	11	52	29.96	30.13	.00	38.8	+0.9	70	18	48	12	14	29	35	33	27	69	1.53	−1.7	13	5,808	ne.	35	w.	6	12	6	13	5.5	0.9	0.4
Wytheville	2,304	49	55	27.65	30.12	−.02	33.8	+0.8	67	18	43	11	14	25	31	29	25	76	1.53	−1.6	14	5,570	w.	34	sw.	18	9	5	17	6.5	1.0	1.0
South Atlantic States							**48.6**	**+3.0**										**76**	**3.65**	**+0.1**										**5.3**		
Asheville	2,253	70	84	27.69	30.12	−.03	38.4	+3.0	65	18	47	17	3	30	29	34	29	73	1.89	−1.2	13	7,126	nw.	31	se.	5	11	12	8	5.2	T.	T.
Charlotte	779	55	62	29.26	30.12	−.03	43.2	+2.0	71	20	52	23	3	34	28	38	34	77	2.58	−1.4	10	3,894	ne.	24	w.	6	10	5	16	5.7	0.0	0.0
Greensboro	886	5	56	29.15	30.13	----	37.8	----	68	20	48	14	3	28	35	32	28	76	1.68	----	11	5,787	ne.	29	w.	6	10	6	15	5.9	T.	0.0
Hatteras	11	11	50	30.09	30.10	−.04	50.4	+3.3	70	25	57	28	9	44	31	46	43	81	4.60	+0.2	13	10,910	n.	42	w.	6	9	14	8	5.3	0.0	0.0
Raleigh	376	103	110	29.71	30.13	.00	43.2	+2.1	70	19	52	22	14	34	34	38	33	74	2.23	−1.4	11	5,553	nw.	30	sw.	6	9	7	15	6.0	0.0	0.0
Wilmington	78	81	91	30.05	30.14	.00	49.8	+3.3	74	20	59	29	3	41	34	45	42	81	5.64	+2.4	10	4,966	w.	32	w.	6	11	10	10	5.3	0.0	0.0
Charleston	48	11	92	30.07	30.12	−.03	53.0	+3.1	76	23	61	32	7	46	28	48	44	79	4.66	+1.6	6	6,837	sw.	32	nw.	6	12	10	9	5.2	0.0	0.0
Columbia, S. C	351	41	57	29.74	30.14	−.01	48.2	+2.2	74	20	57	26	7	39	30	42	38	75	2.82	−0.5	9	4,940	ne.	30	w.	6	10	9	12	5.5	0.0	0.0
Due West	711	10	55	29.37	30.17	----	44.3	----	73	22	54	22	7	35	28	----	----	----	3.05	----	12	6,537	w.	33	w.	6	12	7	12	5.3	~~0.0~~	~~0.0~~
Greenville, S. C	1,039	139	146	28.99	30.11	----	43.3	+3.0	71	20	52	23	3	35	27	38	33	73	3.82	−1.0	13	5,841	ne.	37	w.	31	13	2	16	5.5	0.0	0.0
Augusta	182	62	77	29.92	30.12	−.04	50.4	+3.4	79	22	60	29	3	40	34	44	39	72	3.98	0.0	13	3,375	nw.	21	w.	6	14	7	10	4.8	0.0	0.0
Savannah	65	150	194	30.06	30.13	−.02	55.2	+3.8	79	22	64	30	7	46	29	48	45	78	3.96	+1.2	9	7,875	w.	35	w.	6	13	8	10	4.8	0.0	0.0
Jacksonville	43	209	245	30.08	30.13	−.02	59.5	+4.1	83	21	68	33	3	51	27	53	49	77	3.96	+1.2	10	7,112	sw.	35	sw.	10	13	8	10	4.8	0.0	0.0
Florida Peninsula							**68.8**	**+3.3**										**82**	**1.54**	**−0.9**										**5.0**		
Key West	22	10	64	30.05	30.07	−.03	71.6	+2.1	82	28	76	56	13	67	18	67	65	86	1.41	−0.6	9	6,842	se.	27	nw.	6	16	7	8	4.0	0.0	0.0
Miami	25	71	164	30.08	30.10	−.04	70.4	+3.9	83	28	76	46	13	65	20	66	63	80	1.03	−1.5	4	7,388	e.	26	ne.	29	10	12	9	5.3	0.0	0.0
Tampa	35	79	87	30.08	30.12	.00	64.4	+4.0	83	21	74	39	7	55	29	57	54	79	2.18	−0.5	7	4,061	ne.	17	nw.	12	9	9	13	5.6	0.0	0.0
Titusville	44	5	----	30.06	30.11	----	63.2	----	83	10	72	38	13	55	30	----	----	----	1.86	----	6	----	nw.	----	----	----	----	20	7	4	----	0.0	0.0
East Gulf States							**51.0**	**+2.8**										**76**	**5.50**	**+0.8**										**5.4**		
Atlanta	1,173	190	216	28.86	30.13	−.02	45.2	+2.6	74	22	54	23	7	36	29	40	34	71	4.22	−0.7	14	8,379	nw.	33	nw.	6	13	6	12	5.2	T.	0.0
Macon	370	78	87	29.73	30.14	−.02	49.8	+3.0	78	21	61	21	3	39	33	44	39	73	4.48	+0.3	11	4,368	nw.	23	s.	10	12	5	14	5.5	0.0	0.0
Thomasville	273	49	58	29.83	30.13	−.03	55.8	+4.8	79	21	65	28	7	46	30	50	46	79	4.93	+0.8	10	3,226	sw.	19	sw.	5	10	8	13	5.5	0.0	0.0
Apalachicola	36	42	49	30.08	30.12	----	56.3	----	74	10	64	32	7	49	28	52	50	84	3.77	+0.1	7	5,596	s.	36	se.	5	11	7	13	5.3	0.0	0.0
Pensacola	56	149	185	30.06	30.12	−.02	54.8	+2.3	73	20	62	28	2	48	26	51	47	79	5.40	+1.4	11	9,019	n.	50	se.	5	9	6	16	5.7	0.0	0.0
Anniston	741	9	57	29.34	30.15	−.01	46.0	+3.8	77	18	57	19	3	35	34	----	----	----	4.96	−0.2	14	4,265	se.	21	s.	18	13	9	9	4.7	0.0	0.0
Birmingham	700	11	48	29.36	30.14	−.02	47.8	+2.7	76	18	58	21	12	38	37	42	37	72	5.69	+0.2	11	5,547	s.	32	se.	9	12	5	14	5.3	0.0	0.0
Mobile	57	125	161	30.06	30.12	−.03	53.6	+2.1	75	19	62	28	7	45	27	50	46	80	6.47	+1.6	13	6,865	s.	39	w.	10	7	12	12	5.7	0.0	0.0
Montgomery	223	100	112	29.88	30.14	−.02	51.6	+3.4	79	18	61	25	3	42	29	46	41	70	4.30	−0.9	11	4,954	e.	25	sw.	18	10	12	9	5.4	0.0	0.0
Corinth	469	6	----	----	----	----	43.3	----	74	18	54	18	2	33	41	----	----	----	4.12	----	13	----	s.	----	----	----	6	13	12	----	0.0	0.0
Meridian	375	87	95	29.72	30.12	−.04	49.8	+2.8	79	21	60	20	3	39	36	45	40	75	6.44	+1.1	12	4,231	sw.	22	w.	5	11	9	11	5.3	0.0	0.0
Vicksburg	247	65	73	29.85	30.14	−.01	49.7	+1.5	76	24	59	22	6	40	31	44	39	72	4.78	−0.6	10	5,136	se.	30	se.	5	11	8	12	5.5	0.0	0.0
New Orleans	53	76	84	30.06	30.12	−.01	56.6	+2.4	81	23	65	30	6	49	32	52	49	80	10.63	+6.3	14	4,630	ne.	23	sw.	5	9	12	10	5.5	0.0	0.0
West Gulf States							**49.3**	**+1.0**										**76**	**3.08**	**+0.4**										**5.8**		
Shreveport	249	77	93	29.83	30.11	−.03	47.9	+0.9	75	24	58	21	6	38	38	42	37	69	3.21	−0.7	10	4,606	se.	22	sw.	24	10	5	16	5.9	0.0	0.0
Bentonville	1,303	11	44	28.66	30.07	−.07	33.2	−0.9	64	22	43	8	25	23	35	----	----	----	3.92	----	11	----	s.	----	w.	----	16	5	10	----	2.7	0.0
Fort Smith	457	79	94	29.60	30.10	−.04	37.0	−2.5	67	22	46	14	25	28	28	33	29	75	4.26	+1.7	10	7,256	e.	36	sw.	18	14	5	12	5.2	T.	0.0
Little Rock	357	136	153	29.72	30.12	−.03	38.8	−2.6	71	18	48	17	6	30	32	35	30	71	3.69	−1.0	11	6,092	e.	39	sw.	18	8	6	17	6.5	T.	0.0
Austin	605	136	148	29.42	30.06	----	51.2	+1.7	81	24	62	23	2	40	43	46	43	77	1.85	−0.2	9	5,591	n.	35	nw.	18	8	8	15	6.1	0.0	0.0
Brownsville	57	53	61	29.96	30.02	----	63.1	+3.3	82	18	71	37	6	55	25	58	55	84	0.46	−1.0	8	5,817	s.	26	ne.	25	9	12	10	5.4	0.0	0.0
Corpus Christi	20	11	78	30.03	30.05	−.05	59.8	+3.8	82	24	67	38	2	53	28	56	54	88	0.64	−0.9	8	7,762	se.	37	se.	4	7	7	17	6.5	0.0	0.0
Dallas	512	220	227	29.52	30.08	----	45.0	----	71	19	55	19	25	36	30	----	----	----	3.32	+0.9	7	9,449	se.	43	w.	5	11	8	12	5.4	T.	0.0
Fort Worth	670	106	114	29.33	30.06	−.06	46.1	+0.7	71	19	56	21	25	36	33	40	35	71	2.08	0.0	5	6,415	nw.	31	se.	4	8	11	12	5.7	T.	0.0
Galveston	54	106	114	30.03	30.10	−.03	55.9	+2.1	76	18	62	33	2	50	24	52	50	84	5.53	+2.1	10	7,722	se.	35	n.	25	11	11	9	5.0	0.0	0.0
Groesbeck	461	11	56	29.57	30.07	----	48.4	----	72	23	58	20	2	38	38	----	----	----	3.84	+1.1	9	7,678	n.	33	nw.	5	7	8	16	6.4	~~0.0~~	~~0.0~~
Houston	138	292	314	29.93	30.09	----	55.2	+2.5	78	20	64	27	2	47	27	----	----	----	4.12	+0.4	12	8,960	e.	37	e.	4	9	9	13	5.6	0.0	0.0
Palestine	510	64	72	29.55	30.09	−0.3	48.9	+0.7	75	19	60	22	25	38	38	43	38	72	5.39	+2.0	10	5,539	s.	25	nw.	5	9	7	15	5.9	0.0	0.0
Port Arthur	34	58	66	30.05	30.09	----	54.5	----	75	18	62	29	2	47	25	----	----	----	7.34	----	11	5,328	e.	28	n.	25	11	2	18	6.2	0.0	0.0
San Antonio	693	119	132	29.32	30.06	−.04	53.8	+1.5	83	24	64	28	2	44	36	48	42	70	2.21	+0.8	8	4,680	ne.	32	nw.	5	12	7	12	5.7	0.0	0.0
Taylor	583	55	63	29.48	30.10	−.01	50.0	+2.5	75	19	61	22	2	39	39	----	----	----	2.46	+0.5	9	5,728	s.	28	s.	14	8	10	13	6.0	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau Stations, January, 1929*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. mean min. ÷2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
Ohio Valley and Tennessee	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	° *F.*	° *F.*	°*F.*		°*F.*	°*F.*		°*F.*	°*F.*	°*F.*	°	%	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
							32.7	−1.0										74	4.00	+0.3										6.9		
Chattanooga	762	190	215	29.31	30.14	−0.02	42.4	+1.2	74	18	51	18	12	34	31	37	30	65	5.72	+0.5	13	6,123	sw.	36	se.	9	10	8	13	5.7	T.	0.0
Knoxville	995	102	111	29.04	30.13	−.02	40.6	+1.8	74	18	49	20	8	32	30	36	31	74	4.34	−0.3	14	5,108	ne.	42	s.	18	7	12	12	6.0	0.1	0.0
Memphis	399	76	97	29.68	30.12	−.04	40.4	−0.5	72	18	50	16	2	31	37	36	31	74	3.95	−0.9	9	5,564	e.	34	w.	5	9	5	17	6.4	T.	0.0
Nashville	546	168	191	29.55	30.15	−.01	39.2	+0.6	74	18	49	16	2	30	40	35	29	71	3.85	−0.9	11	7,329	w.	38	sw.	18	8	7	16	6.5	T.	0.0
Lexington	989	193	230	29.03	30.14	+.01	32.0	−0.9	72	18	42	2	13	22	41				2.83	−1.4	15	10,221	sw.	48	sw.	18	4	8	19	6.8	2.8	0.2
Louisville	525	188	234	29.54	30.14	.00	31.8	−2.6	72	18	41	4	13	22	34	29	25	77	3.77	−0.2	13	8,087	s.	48	s.	18	8	6	17	6.5	2.5	T.
Evansville	431	76	116	29.67	30.15	+.01	31.2	−2.3	70	18	40	5	13	22	35	28	23	73	4.61	+0.9	15	7,499	s.	42	w.	18	6	12	13	6.5	3.5	T.
Indianapolis	822	194	230	29.18	30.10	−.04	25.0	−3.4	64	18	34	−1	31	16	33	23	18	76	4.74	+1.8	16	8,912	nw.	39	w.	22	5	11	15	6.8	8.1	2.8
Royal Center	736	11	55	29.27	30.11	------	19.2	------	52	18	29	−7	31	19	31				3.88	+1.6	13	8,362	w.	36	w.	22	7	6	18	6.8	9.3	3.4
Terre Haute	575	96	129	29.47	30.11	------	25.4	------	60	18	35	0	13	16	32	23	18	74	4.75	+2.0	15	7,091	nw.	35	w.	22	8	9	14	6.4	6.9	0.5
Cincinnati	627	11	51	29.42	30.12	.00	29.2	−1.1	70	18	38	−1	14	20	36	26	23	83	4.60	+1.1	16	6,127	sw.	38	sw.	18	7	7	17	7.0	8.2	3.7
Columbus	822	179	222	29.19	30.10	−.01	27.7	−0.9	67	18	36	0	14	19	32	24	21	79	3.54	+0.5	17	8,480	nw.	42	w.	19	4	8	19	7.4	7.7	2.0
Dayton	899	137	173	29.11	30.11	------	27.4	−2.1	67	18	36	−2	14	18	33	24	19	75	4.34	+1.1	16	7,431	nw.	44	sw.	18	6	5	20	7.4	11.1	2.8
Elkins	1,947	59	67	27.98	30.13	+.01	31.2	+0.8	67	18	42	−10	14	20	44	27	23	76	3.21	−0.6	21	5,477	w.	35	nw.	25	2	8	21	8.1	11.0	2.8
Parkersburg	637	77	82	29.45	30.13	+.01	31.2	−1.3	72	18	40	−4	14	22	34	27	22	72	2.57	−1.0	18	4,855	sw.	36	w.	25	5	3	23	7.9	7.4	1.2
Pittsburgh	842	353	410	29.16	30.10	−.01	28.0	−2.7	69	18	37	−4	14	19	34	25	19	69	3.33	+0.3	17	8,901	w.	50	w.	25	4	4	23	7.5	10.5	1.2
Lower Lake Region							23.2	−1.3										79	3.64	+1.0										7.6		
Buffalo	767	247	280	29.14	30.00	−.07	23.7	−0.9	62	18	31	−1	14	16	34	21	18	83	3.73	+0.4	23	16,369	w.	70	sw.	6	4	6	21	7.6	20.7	2.0
Canton	448	10	61	29.47	29.98	------	17.2	+0.9	61	18	27	−12	14	7	49				3.31	+0.8	21	8,647	w.	51	sw.	19	6	11	14	6.5	11.0	2.2
Ithaca	836	5	100	29.07	30.01	------	23.6	------	59	18	31	0	14	16	33	21	17	77	1.98	−0.2	22	9,322	nw.	48	se.	25	4	7	20	7.5	12.2	8.0
Oswego	335	76	91	29.62	30.00	−.07	24.4	+0.5	58	18	31	3	14	18	35	22	19	82	3.72	+0.8	25	10,002	nw.	35	w.	20	1	1	29	2.1	48.1	6.2
Rochester	523	86	102	29.42	30.02	−.05	24.4	−0.2	62	18	31	−1	14	18	32	21	16	73	3.22	+0.3	24	8,340	w.	40	sw.	19	0	7	24	8.6	22.9	7.0
Syracuse	596	65	79	29.37	30.03	−.04	24.9	+1.9	62	19	33	2	14	17	41				2.96	−0.1	22	6,999	sw.	34	sw.	19	1	10	20	8.0	27.8	7.0
Erie	714	130	166	29.25	30.04	−.04	25.3	−1.5	65	18	32	−2	14	18	31	22	17	72	3.26	+0.5	18	12,693	w.	54	se.	5	0	5	26	8.6	13.4	1.0
Cleveland	762	190	201	29.22	30.07	−.02	25.0	−1.5	61	18	33	−4	14	17	35	22	18	78	5.23	+2.7	22	10,915	w.	50	w.	18	1	10	20	7.8	16.6	0.8
Sandusky	629	5	67	29.38	30.09	.00	23.8	−2.5	59	18	32	−3	14	16	30				4.00	+1.7	19	7,676	sw.	32	sw.	25	5	10	16	6.7	16.6	1.9
Toledo	628	208	243	29.37	30.08	−.01	23.1	−2.7	55	18	31	−3	14	15	32	20	16	76	3.72	+1.6	19	10,461	w.	49	w.	25	6	10	15	6.6	15.8	1.8
Fort Wayne	856	113	124	29.11	30.07	------	21.4	−5.5	54	18	30	−5	14	13	33	20	17	81	4.23	+1.9	16	7,218	w.	32	w.	22	5	7	19	7.1	12.1	1.3
Detroit	730	218	258	29.23	30.05	−.03	21.8	−2.6	50	18	29	−3	14	14	29	20	18	87	4.27	+2.2	19	8,580	w.	38	sw.	25	7	7	17	6.7	22.1	2.2
Upper Lake Region							12.2	−6.3										84	3.44	+1.5										6.9		
Alpena	609	13	92	29.29	29.99	−.05	15.7	−3.4	40	6	23	−9	13	8	31	14	11	82	2.86	+1.0	14	9,163	w.	48	se.	22	5	9	17	7.2	25.8	8.6
Escanaba	612	54	60	29.23	30.04	−.01	7.4	−8.0	33	22	17	−19	14	−2	34	6	3	83	2.83	+1.3	13	6,954	nw.	37	n.	5	13	8	10	4.8	31.6	18.5
Grand Haven	632	54	89	29.33	30.05	−.02	19.0	−5.3	41	5	25	−1	13	13	27	18	16	88	4.39	+2.0	27	9,402	w.	40	sw.	25	0	3	28	9.1	27.1	9.1
Grand Rapids	707	70	87	29.25	30.05	−.01	18.8	−5.7	41	5	25	−2	13	12	24	17	14	81	4.00	+1.6	18	5,126	w.	24	w.	22	0	7	24	8.9	30.8	7.5
Houghton	668	64	99	29.25	30.02	−.03	8.0	−6.7	28	22	15	−13	13	1	33				6.33	+3.9	24	8,203	w.	38	w.	22	0	8	23	8.9	61.0	37.4
Lansing	878	6	49	29.06	30.04	------	17.2	−5.2	42	18	25	−7	13	9	29	16	15	94	3.42	+1.6	22	5,163	w.	26	w.	22	5	7	19	7.4	24.9	7.3
Ludington	637	60	66	29.30	30.02	------	17.3	------	39	5	23	−3	13	11	27	17	14	85	3.49	+1.4	24	8,941	w.	38	w.	22	1	4	26	8.7	30.0	12.8
Marquette	734	77	111	29.17	30.02	−.02	10.2	−6.1	30	5	18	−13	14	2	28	8	5	84	3.73	+1.4	14	7,748	w.	42	nw.	23	7	11	13	6.1	37.8	22.0
Port Huron	638	70	120	29.31	30.04	−.02	19.6	−2.7	46	18	28	−6	14	12	31	18	15	84	2.61	+0.8	17	9,174	w.	42	w.	23	8	11	12	5.7	18.7	3.2
Sault Ste. Marie	614	11	52	29.25	29.99	−.04	9.6	−3.7	33	6	18	−25	14	2	26	8	7	92	3.57	+1.6	20	7,075	sw.	36	nw.	23	2	6	23	8.4	35.4	24.0
Chicago	673	7	131	29.33	30.10	.00	17.6	−6.1	43	22	26	−9	13	9	32	16	11	75	3.93	+2.0	16	8,023	nw.	34	sw.	25	8	7	16	6.1	17.5	3.4
Green Bay	617	109	141	29.35	30.06	.00	5.8	−9.9	35	22	15	−24	14	−3	36	5	3	88	2.54	+1.0	16	6,956	sw.	36	sw.	22	12	8	11	5.4	27.5	19.2
Milwaukee	681	125	221	29.29	30.07	−.01	12.4	−8.2	42	5	22	−18	13	3	34	11	7	79	3.00	+1.2	18	10,146	w.	37	w.	22	10	10	11	5.8	24.9	7.6
Duluth	1,133	5	47	28.79	30.10	+.01	−2.6	−10.5	26	21	7	−34	13	−12	30	−4	−8	77	1.51	+0.5	13	9,274	nw.	56	nw.	22	15	8	8	4.1	20.1	20.0
North Dakota							−4.4	−9.3										86	0.82	+0.3										5.5		
Moorhead	940	50	58	29.11	30.21	+.07	−4.6	−8.4	29	10	5	−28	13	−14	39	−5	−7	88	1.36	+0.7	11	5,076	n.	28	n.	22	11	7	13	5.7	18.1	11.1
Bismarck	1,674	8	57	28.28	30.20	+.07	−2.9	−10.7	38	10	8	−33	29	−14	45	−4	−6	86	0.69	+0.2	11	4,935	nw.	40	nw.	10	9	12	10	5.6	8.8	5.5
Devils Lake	1,478	11	44	28.48	30.20	+.08	−7.1	−8.9	29	8	3	−32	13	−17	47	−9	−10	93	0.41	−0.1	8	5,590	w.	35	n.	10	14	7	10	4.8	5.5	3.5
Ellendale	1,457	10	56	28.52	30.18	------	−1.6	------	39	8	8	−26	29	−12	44				0.74	+0.3	14	8,274	nw.	46	nw.	22	9	10	12	5.8	10.9	6.5
Grand Forks	833	12	67	------	------	------	−7.0	------	23	8	2	−32	13	−17	33				0.74	------	7	------	nw.	----	n.	10	13	11	7	----	11.1	10.8
Williston	1,878	41	48	28.08	30.20	+.09	−2.8	−9.2	38	10	8	−34	29	−14	48	−4	−8	79	0.90	+0.4	15	4,689	w.	36	nw.	10	9	9	13	5.8	10.9	7.6
Upper Mississippi Valley							13.8	−7.8										81	2.95	+1.4										6.1		
Minneapolis	918	102	208	29.07	30.12	------	2.0	−10.7	37	8	10	−24	13	−6	38				1.60	+0.7	17	7,133	nw.	38	nw.	22	10	5	16	5.9	18.3	14.5
St. Paul	837	236	261	29.18	30.15	+.04	1.9	−10.7	34	8	10	−24	13	−6	39				1.52	+0.6	15	7,216	w.	40	w.	22	9	5	17	6.2	19.9	13.6
La Crosse	714	11	48	29.31	30.14	+.03	4.3	−11.8	29	11	14	−25	15	−5	40	3	−1	79	3.42	+2.3	18	3,282	nw.	17	nw.	11	9	8	14	6.0	39.6	28.5
Madison	974	70	78	28.99	30.11	+.01	6.4	−10.3	36	22	16	−21	13	−3	35	6	3	84	3.31	+1.9	20	5,602	nw.	30	w.	22	10	9	12	5.7	31.8	19.4
Wausau	1,247	4	64	------	30.07	------	2.0	------	25	22	11	−28	13	−7	36				2.75	+1.5	15	------	w.	----	----	12	8	11	----	32.9	23.0
Charles City	1,015	10	51	29.00	30.15	+.013	4.6	−9.1	36	9	14	−22	15	−5	37	4	1	87	2.68	+1.6	13	4,648	nw.	25	w.	22	10	6	15	5.6	26.9	18.2
Davenport	606	71	79	29.43	30.14	+.02	13.7	−8.1	41	22	23	−11	7	5	35	12	10	85	3.01	+1.6	13	7,292	nw.	36	nw.	22	9	7	15	6.2	15.6	8.0
Des Moines	861	84	97	29.18	30.15	+.01	11.6	−8.5	38	9	21	−10	7	2	37	11	8	84	2.70	+1.6	10	5,236	n.	25	nw.	11	9	6	16	6.3	21.4	10.0
Dubuque	700	81	96	29.33	30.13	+.01	9.6	−9.5	36	22	19	−16	13	0	36	9	4	79	3.13	+1.8	15	4,408	nw.	23	nw.	11	6	9	16	6.6	34.3	20.1
Keokuk	614	64	78	29.44	30.16	+.02	17.6	−7.3	46	22	27	−8	7	8	35	16	12	78	3.14	+1.6	12	5,690	nw.	30	nw.	11	11	5	15	6.0	9.4	3.8
Cairo	358	87	93	29.74	30.14	+.02	33.4	−1.5	70	18	42	13	6	24	37	31	27	77	4.98	+1.2	11	7,275	ne.	48	sw.	18	7	8	16	6.9	T.	0.0
Peoria	609	11	45	29.43	30.13	+.01	17.8	−5.3	46	18	27	−8	7	8	35	16	14	85	3.98	+2.2	13	5,501	nw.	27	w.	11	12	7	12	5.4	10.1	2.5
Springfield, Ill	636	154	191	29.40	30.11	−.02	21.2	−5.3	53	22	31	−5	7	12	33	19	16	80	2.58	+0.5	13	9,262	nw.	38	w.	25	8	7	16	6.5	4.3	0.5
Hannibal	534	74	109	29.53	30.13	.00	21.0	−6.1	56	22	30	−3	13	12	39				3.33	+1.6	15	6,373	nw.	30	w.	22	11	6	14	5.9	8.0	2.0
St. Louis	568	265	303	29.49	30.12	−.02	27.6	−3.2	61	22	38	3	13	18	34	24	20	75	2.11	−0.2	12	9,165	nw.	41	sw.	22	12	6	13	5.6	3.3	T.
Missouri Valley							15.7	−7.2										79	1.69	+0.7										6.1		
Columbia, Mo	784	6	84	29.25	30.12	−.01	23.5	−5.7	63	22	34	0	2	14	47				2.09	+0.2	9	6,360	e.	33	n.	11	9	9	13	6.0	4.7	0.0
Kansas City	963	161	181	29.05	30.13	−.02	21.0	−7.2	53	18	31	0	25	12	35	19	14	75	3.12	+1.9	10	7,793	n.	35	nw.	11	7	9	15	6.3	10.2	T.
St. Joseph	967	11	49	29.05	30.14	------	18.2	------	42	8	27	−3	25	9	36	16	12	78	2.96	+1.9	9	6,365	nw.	37	nw.	22	11	6	14	5.7	9.9	0.8
Springfield, Mo	1,324	98	104	28.65	30.10	−.04	29.4	−4.1	65	22	40	5	25	19	42	27	23	82	2.53	+0.2	9	8,581	s.	38	w.	22	12	6	13	5.5	1.8	0.0
Iola	984	11	50	29.01	30.11	−.03	26.2	−3.6	57	22	36	3	25	16	40				2.38	+1.1	9	4,880	n.	24	n.	5	10	5	16	6.3	1.0	0.0
Topeka	987	92	107	------	------	------	21.0	−6.6	48	18	30	0	31	12	34				2.42	+1.5	9	6,827	n.	33	n.	11	10	8	13	6.0	10.2	0.4
Lincoln	1,189	11	81	28.81	30.15	.00	15.4	−7.4	43	12	24	−6	25	6	32	14	8	72	0.61	0.0	5	7,209	n.	44	nw.	22	7	6	18	6.3	4.8	T.
Omaha	1,105	115	122	28.91	30.16	+.01	13.6	−8.3	42	10	22	−8	25	5	34	12	8	78	1.15	+0.4	11	6,297	nw.	35	nw.	11	9	9	13	5.9	9.3	0.7
Valentine	2,598	47	54	27.28	30.16	+.04	11.1	−7.8	53	8	24	−24	25	−1	43	9	5	81	1.13	+0.6	17	5,596	w.	34	nw.	22	7	11	13	6.0	18.3	2.2
Sioux City	1,135	94	164	28.88	30.18	+.03	9.3	−8.5	47	10	18	−13	7	0	37	9	6	84	0.59	−0.2	12	8,534	nw.	51	nw.	22	7	10	14	6.5	6.1	2.8
Huron	1,306	59	74	28.72	30.21	+.05	3.0	−8.3	44	10	14	−26	29	−8	42	2	−1	80	1.50	+0.9	15	5,632	nw.	35	nw.	22	7	7	17	6.6	16.1	9.7
Pierre	1,572	70	75	------	30.23	+.10	5.5	−10.5	47	10	16	−26	25	−5	46	----	----	80	0.95	+0.5	15	5,543	nw.	47	nw.	10	7	10	14	----	9.6	6.0
Yankton	1,233	49	57	28.77	30.18	+.02	8.9	−8.4	46	10	19	−15	29	−1	39				0.55	0.0	10	5,687	nw.	35	nw.	10	8	5	18	6.5	6.3	3.0

TABLE 1.—*Climatological data for Weather Bureau Stations, January, 1929*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	° F.	° F.	°F.		°F.	°F.		°F.	F°.	°F.	°F.	%	In.	In.		Miles							0–10	In.	In.
Northern Slope							10.8	−8.5										78	0.80	0.0									6.4		
Billings	3,140	5					11.4		48	13	22	−33	31	1	42				0.80		10		nw.				14	4	13		12.5	
Havre	2,505	11	44	27.40	30.22	+.12	2.2	−10.7	43	11	12	−39	28	−7	36	2	−2	80	0.61	−0.1	13	4,844	sw.	28	sw.	9	4	9	18	7.1	8.8	5.8
Helena	4,110	87	112	25.74	30.16	+.01	9.5	−10.7	48	13	18	−32	28	1	27	8	4	79	1.28	+0.4	17	4,162	sw.	30	sw.	10	4	6	21	7.8	16.9	10.5
Kalispell	2,973	48	56	26.94	30.18	+.06	10.2	−10.2	34	13	17	−23	23	4	29	10	8	88	1.97	+0.4	15	3,153	nw.	22	n.	25	3	11	17	7.2	20.6	20.0
Miles City	2,371	48	55	27.51	30.23	+.11	3.0	−11.5	43	11	14	−38	31	−8	43	2	0	84	0.90	+0.2	16	3,987	s.	33	nw.	10	10	5	16	6.2	11.7	7.5
Rapid City	3,259	50	58	26.56	30.20	+.10	10.2	−11.8	47	8	21	−20	31	−1	43	7	1	70	0.44	0.0	10	4,599	se.	37	n.	10	9	12	10	5.5	4.5	2.4
Cheyenne	6,088	84	101	23.82	30.00	−.05	22.1	−3.4	50	13	33	−5	19	11	36	18	10	63	0.32	−0.1	10	9,679	w.	49	w.	12	9	9	13	5.7	3.6	T.
Lander	5,372	60	68	24.49	30.11	−.01	10.6	−7.7	52	12	23	−20	24	−2	45	8	6	88	0.15	−0.4	2	2,246	e.	24	nw.	30	12	15	4	4.3	2.2	3.6
Sheridan	3,790	10	47	26.03	30.15		8.2		46	13	20	−29	24	−4	36	6	2	75	0.99	+0.1	15	2,965	nw.	24	nw.	21	6	15	10	6.1	10.8	7.3
Yellowstone Park	6,241	11	48	23.73	30.09	−.05	10.7	−6.9	33	12	20	−26	23	1	38	9	6	80	1.09	−0.5	19	4,395	sw.	24	sw.	25	4	6	21	7.7	14.1	13.8
North Platte	2,821	11	51	27.04	30.11	−.01	19.0	−3.9	53	12	30	−7	25	8	44	15	11	77	0.23	−0.2	4	4,979	n.	30	n.	9	9	9	13	6.2	2.6	T.
Middle Slope							27.4	−3.1										70	0.89	+0.3									5.2		
Denver	5,292	106	113	24.58	29.98	−.07	27.6	−2.2	61	13	38	0	24	17	39	23	13	55	0.14	−0.3	3	4,683	s.	29	n.	9	14	11	6	4.5	2.8	0.0
Pueblo	4,685	80	86	25.17	29.98	−.07	29.6	−0.3	63	12	43	−2	25	16	49	23	15	59	0.19	−0.1	6	4,408	nw.	30	nw.	22	16	9	6	4.0	3.2	0.0
Concordia	1,392	50	58	28.61	30.16	+.02	20.6	−5.8	51	12	29	−1	31	12	35	18	13	74	0.78	+0.2	7	5,583	nw.	30	nw.	11	9	10	12	6.2	5.1	T.
Dodge City	2,509	11	51	27.41	30.12	+.01	26.0	−3.0	58	12	36	1	25	16	35	22	18	78	0.56	+0.2	4	6,306	se.	29	nw.	22	12	10	9	5.0	6.7	T.
Wichita	1,358	139	158	28.61	30.10	−.03	26.4	−4.9	49	17	35	4	31	18	26	24	20	78	2.08	+1.3	8	8,512	s.	34	nw.	22	10	13	8	5.1	3.0	0.0
Broken Arrow	765	11	56	29.25	30.10		33.0		63	22	43	11	25	23	35				2.55		8	8,915	n.	37	nw.	5	10	7	14	6.1	2.8	0.0
Oklahoma City	1,214	10	47	28.76	30.08	−.03	34.2	−2.2	64	19	44	11	25	24	37	30	26	75	1.61	+0.4	8	7,431	n.	34	n.	5	10	8	13	5.6	0.3	0.0
Southern Slope							43.5	+0.7										60	0.27	−0.4									4.6		
Abilene	1,738	10	52	28.21	30.06	−.03	44.6	+0.4	72	19	56	14	25	33	38	36	27	57	0.48	−0.5	4	6,769	s.	32	w.	18	11	8	12	5.3	T.	0.0
Amarillo	3,676	10	49	26.21	30.02	−.04	36.4	+1.1	62	30	48	2	25	24	48	29	23	66	0.16	−0.4	4	6,268	sw.	25	n.	5	12	12	7	4.5	1.0	0.0
Del Rio	944	64	71	29.02	30.02	−.04	53.2	+0.9	82	24	63	28	2	43	33	46	38	64	0.42	−0.1	5	5,317	se.	30	n.	25	13	7	11	4.7	0.0	0.0
Roswell	3,566	75	85	26.32	30.00	−.04	39.7	+0.5	69	30	55	12	25	24	46	32	22	53	0.03	−0.5	1	4,339	s.	38	nw.	24	16	9	6	4.0	0.4	0.0
Southern Plateau							40.5	−0.2										52	0.52	−0.5									3.7		
El Paso	3,778	152	175	26.17	30.00	−.01	45.4	+0.4	73	21	58	22	25	33	36	35	20	39	T.	−0.5	0	6,814	w.	41	w.	8	20	8	3	3.0	T.	0.0
Santa Fe	7,013	38	53	23.13	30.01	−.03	28.9	+0.1	51	21	39	6	6	18	28	22	13	56	0.27	−0.4	6	4,374	n.	23	sw.	17	16	6	9	4.3	4.3	0.0
Flagstaff	6,907	10	59	23.24	29.96	−.09	27.0	+0.3	58	13	39	−6	24	14	41	23		72	1.76	−1.1	8		sw.		ne.	10	8	16	7		16.0	4.5
Phoenix	1,108	10	82	28.82	29.99	−.04	50.1	−1.1	72	12	63	27	25	37	37	41	29	50	0.92	+0.1	5	3,284	e.	27	nw.	23	11	11	9	4.8	0.0	0.0
Yuma	141	9	54	29.86	30.01	−.04	51.6	−2.8	75	13	66	30	7	38	35	41	27	42	0.14	−0.3	1	3,147	n.	22	n.	9	20	9	2	2.7	0.0	0.0
Independence	3,957	6	27	25.95	30.04	−.03	39.8	+1.6	68	11	54	13	22	26	42	29			0.03	−0.9	1		nw.				13	8	10		T.	0.0
Middle Plateau							25.7	−2.5										73	0.96	−0.1									5.2		
Reno	4,532	74	81	25.45	30.09	−.04	31.6	−0.9	54	31	43	5	21	20	35	27	21	66	0.44	−1.1	3	4,368	w.	40	w.	18	15	8	8	4.2	6.5	0.0
Tonopah	6,090	12	20				26.1		43	14	31	2	24	21	23	24	19	72	0.70		4		se.									
Winnemucca	4,344	18	56	25.61	30.11	−.05	27.4	−1.2	51	14	39	−10	21	16	39	23	18	68	0.59	−0.4	8	5,379	sw.	26	sw.	29	12	12	7	4.6	3.9	0.0
Modena	5,473	10	43	24.55	30.05	−.05	23.7	−3.0	51	13	36	−23	24	11	43	20	16	76	1.29	+0.4	7	6,078	sw.	30	s.	18	11	9	11	5.1	21.3	3.6
Salt Lake City	4,360	163	203	25.59	30.08	−.07	26.4	−2.8	44	29	33	−1	24	20	25	24	20	78	1.53	+0.2	14	3,995	nw.	26	s.	27	5	9	17	7.1	17.7	3.3
Grand Junction	4,802	60	68	25.36	30.06	.00	19.5	−4.5	44	30	31	−8	27	8	33	17	14	80	0.95	+0.4	10	2,231	n.	18	nw.	23	13	9	9	5.0	10.0	1.0
Northern Plateau							20.1	−8.6										83	2.03	+0.3									7.6		
Baker	3,471	48	53	26.45	30.18	+.02	16.0	−8.9	37	18	25	−14	20	7	26	16	13	85	1.98	+0.6	15	3,552	se.	18	se.	28	4	13	14	6.9	29.6	17.2
Boise	2,739	78	86	27.22	30.20	+.01	23.1	−6.7	42	26	30	−7	23	16	23	22	18	80	2.49	+0.8	13	2,577	se.	20	se.	29	4	13	14	6.9	27.0	12.3
Lewiston	757	40	48	29.33	30.18	+.02	24.5	−8.0	46	1	31	−5	23	18	20				2.14	+0.6	14	1,804	e.	15	ne.	1	3	7	21	8.0	24.1	13.0
Pocatello	4,477	60	68	25.42	30.14	−.06	17.2	−7.5	36	2	26	−20	21	8	40	16	12	81	2.02	+0.6	15	5,036	se.	26	sw	26	4	9	18	7.0	25.1	18.0
Spokane	1,929	101	110	28.04	30.19	+.07	17.8	−9.7	36	1	22	−17	30	13	29	17	14	80	1.18	−1.0	10	2,800	ne.	17	ne.	18	2	4	25	8.5	18.0	12.0
Walla Walla	991	57	65	29.07	30.19	+.04	21.8	−10.9	49	2	27	−4	30	17	28	21	19	89	2.37	+0.4	15	2,113	w.	14	w.	17	2	7	22	8.6	30.6	20.0
North Pacific Coast Region							36.1	−4.3										85	2.77	−3.5									7.9		
North Head	211	11	56	29.86	30.10	+.05	38.6	−3.5	53	9	43	25	19	34	19	37	35	87	3.44	−5.3	17	8,319	e.	48	w.	29	5	7	19	7.0	8.4	1.6
Port Angeles	29	8	53		30.09		34.7		50	17	40	14	30	30	20				1.38	−4.1	10	4,475	s.	34	n.	18	2	5	24		10.6	5.2
Seattle	125	215	250	29.96	30.09	+.04	34.6	−4.9	47	1	39	18	28	30	20	33	30	84	2.54	−2.4	13	4,923	ne.	36	sw.	25	3	8	20	7.7	11.1	3.7
Tacoma	194	172	201	29.87	30.08	+.04	33.9	−4.9	50	1	39	15	23	29	19				2.58	−3.6	14	4,954	n.	34	n.	22	1	6	24	8.4	11.9	7.0
Tatoosh Island	86	9	53	29.96	30.06	+.08	38.7	−2.5	48	17	41	20	27	36	18	37	36	88	3.28	−8.6	12	11,974	e.	55	e.	28	5	8	18	7.3	5.2	0.2
Yakima	1,076	58	67	28.99	30.20		16.9		41	17	24	−8	30	10	31	17	14	85	1.50	+0.2	10	1,974	w.	24	ne.	18	3	6	22	8.1	21.3	17.0
Medford	1,425	4	80	28.57	30.12		34.8		54	13	42	14	20	27	32	33	30	86	1.47		13		se.	19	nw.	18	5	7	19	7.3	3.0	0.0
Portland, Oreg.	153	68	106	29.96	30.12	+.04	34.2	−5.2	51	1	39	15	29	29	18	32	29	79	3.50	−3.1	14	3,730	e.	29	e.	18	2	7	22	8.1	13.2	6.2
Roseburg	510	75	99	29.56	30.13	+.03	36.4	−4.8	51	1	41	19	20	32	16	36	34	87	3.95	−1.4	16	2,474	sw.	18	n.	19	0	7	24	9.0	2.2	0.0
Middle Pacific Coast Region							44.2	−3.1										83	1.77	−2.8									6.1		
Eureka	62	73	89	30.04	30.11	+.01	45.0	−1.9	58	30	51	32	21	39	20	43	41	84	4.31	−2.8	17	3,712	se.	25	n.	23	8	6	17	6.1	T.	0.0
Red Bluff	330	54	58	29.72	30.09	−.03	41.8	−4.0	66	9	49	27	11	34	36	39	34	79	1.47	−3.3	6	3,565	s.	24	se.	19	10	5	16	5.9	7.1	0.0
Sacramento	69	106	117	30.02	30.09	−.03	41.2	−4.6	58	30	46	30	24	36	22	40	39	90	0.88	−2.8	5	4,064	se.	23	nw.	23	4	7	20	7.6	0.0	0.0
San Francisco	155	208	243	29.91	30.08	−.03	47.4	−2.5	59	30	53	36	12	42	17	44	41	79	1.32	−3.2	6	4,144	nw.	19	w.	19	11	7	13	5.6	0.0	0.0
San Jose	141	12	110	29.93	30.09		45.6	−2.7	65	30	56	28	12	36	30				0.86	−2.1	8	2,881	se.	17	nw.	18	9	10	12	5.3	0.0	0.0
South Pacific Coast Region							50.9	−0.8										72	1.12	−1.2									5.4		
Fresno	327	89	98	29.74	30.11	+.01	43.0	−3.2	65	30	50	27	15	36	22	40	37	81	1.26	−0.5	6	2,355	nw.	24	nw.	23	6	8	17	7.0	T.	0.0
Los Angeles	338	159	191	29.67	30.04	−.04	55.2	+0.6	81	12	63	41	25	48	26	48	41	64	1.20	−1.9	5	3,417	ne.	16	sw.	16	13	10	8	4.4	0.0	0.0
San Diego	87	62	70	29.94	30.03	−.04	54.4	+0.1	70	12	62	39	22	47	24	48	43	71	0.90	−1.2	6	3,595	e.	22	w.	20	11	12	8	4.9	0.0	0.0
West Indies																															
San Juan, P. R.	82	9	54	29.94	30.03		75.0	0.0	85	30	80	66	30	70	19				3.60	−1.0	25	9,502	e.	40	e.	5	10	18	3	4.8	0.0	0.0
Panama Canal																															
Balboa Heights	118	7	97	[1]29.74	[2]29.81	−.03	79.4	−0.5	89	17	88	66	30	71	21	72	71	[3]78	0.17	−0.7	2	6,289	nw.	22	n.	14	11	19	1	4.3	0.0	0.0
Cristobal	38	7	97	[1]29.81	[2]29.83	−.03	81.4	+0.4	88	4	86	70	28	76	17	74	72	[3]76	0.81	−2.7	9	9,751	n.	28	n.	14	7	22	2	4.8	0.0	0.0
Alaska																															
Juneau	80	11	50	[1]30.04	[2]30.13		30.7		46	12	34	12	26	27	17	29	25	79	9.09		20	4,787	e.	27	e.	25	7	4	20	7.5	25.4	4.9
Hawaiian Islands																															
Honolulu	38	86	100	[1]29.90	[2]29.94		70.8		78	2	76	59	24	66	14	64	60	71	4.80	+1.0	13	5,855	ne.	29	ne.	22	18	7	6	4.0	0.0	0.0

[1] Pressure not reduced to mean of 24 hours.

[2] Observations taken hourly.

TABLE 2.—*Data furnished by the Canadian Meteorological Service, January, 1929*

Station	Altitude above mean sea level, Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷ 2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*Inches*	*Inches*	*Inches*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*Inches*	*Inches*	*Inches*
Cape Race, N. F.	99				26.2		33.7	18.6	47	0	6.17		15.3
Sydney, C. B. I.	48	29.66	29.71	−0.22	22.9	+1.4	30.3	15.4	52	−2	5.45	+0.35	18.5
Halifax, N. S.	88	29.71	29.82	−.15	24.1	+2.3	33.2	15.0	55	−6	5.35	−0.42	9.8
Yarmouth, N. S.	65	29.73	29.80	−.20	26.9	+0.6	34.7	19.1	55	4	7.37	+2.21	38.8
Charlottetown, P. E. I.	38	29.66	29.70	−.26	19.3	+2.3	26.7	11.9	50	−12	3.23	−0.73	25.3
Chatham, N. B.	28	29.67	29.71	−.26	12.8	+3.0	22.8	2.9	52	−20	2.59	−1.00	15.1
Father Point, Que.	20												
Quebec, Que.	296	29.58	29.92	−.10	9.0	−0.1	17.2	0.8	43	−22	4.44	+0.43	31.1
Doucet, Que.	1,236				−4.2		11.3	−19.8	30	−64	5.10		51.0
Montreal, Que.	187	29.73	29.96	−.08	14.2	+2.5	22.8	5.6	48	−15	5.61	+1.88	29.4
Ottawa, Ont.	236	29.71	29.99	−.04	12.8	+3.2	22.0	3.6	46	−21	4.45	+1.46	23.8
Kingston, Ont.	285	29.66	30.00	−.05	19.8	+2.7	28.1	11.6	51	−10	3.48	+0.03	10.7
Toronto, Ont.	379	29.58	30.01	−.04	23.0	+1.6	29.4	16.7	45	−1	5.46	+2.54	14.4
Cochrane, Ont.	930				−5.1		3.6	−13.7	24	−40	1.82		18.2
White River, Ont.	1,244												
London, Ont.	808				19.2		26.5	12.0	44	−6	6.44		28.0
Southampton, Ont.	656												
Parry Sound, Ont.	688	29.23	29.97	−.04	12.8	−1.0	21.3	4.3	40	−19	8.30	+4.22	71.0
Port Arthur, Ont.	644	29.30	30.06	−.01	−0.6	−3.7	8.6	−9.7	27	−30	1.85	+1.03	18.5
Winnipeg, Man.	760												
Minnedosa, Man.	1,690												
Le Pas, Man.	860												
Qu'Appelle, Sask.	2,115	27.76	30.20	+.12	−9.4	−5.6	0.8	−19.5	33	−38	0.48	−0.02	4.8
Moose Jaw, Sask.	1,759												
Swift Current, Sask.	2,392												
Medicine Hat, Alb.	2,144												
Calgary, Alb.	3,428												
Banff, Alb.	4,521												
Prince Albert, Sask.	1,450												
Battleford, Sask.	1,592												
Edmonton, Alb.	2,150												
Kamloops, B. C.	1,262	28.89	30.26	+.30	13.7	−9.3	18.3	9.1	34	−22	1.80	+0.98	18.0
Victoria, B. C.	230	29.84	30.10	+.13	35.1	−3.4	38.6	31.5	48	14	2.33	−3.06	11.9
Barkerville, B. C.	4,180	25.60	30.09	+.20	9.1	−8.7	16.2	2.1	35	−34	3.30	+0.70	33.0
Estevan Point, B. C.	20				36.3		42.6	30.0	48	12	3.97		15.0
Prince Rupert, B. C.	170				35.2		39.7	30.7	49	8	5.98		1.8
Hamilton, Ber.	151	30.03	30.20	+.07	62.6	+0.6	69.2	56.1	75	49	3.62	−1.32	0.0

LATE REPORTS, DECEMBER, 1928

Moose Jaw, Sask.	1,759												
Winnipeg, Man.	760	29.16	30.03	+.01	17.6	+13.5	24.2	11.1	44	−16	0.35	−0.56	3.2
Medicine Hat, Alb.	2,144	27.64	29.96	−.01	26.4	+8.2	36.8	16.0	57	−26	0.25	−0.30	2.5
Calgary, Alb.	3,428	26.35	30.04	+.10	25.1	+6.9	37.3	13.0	57	−21	0.22	−0.37	2.2
Banff, Alb.	4,521	25.35	30.14	+.20	17.0	−2.1	24.4	9.6	38	−24	0.61	−0.60	6.1
Edmonton, Alb.	2,150	27.57	29.93	.00	20.0	+6.9	29.3	10.8	52	−25	0.50	−0.20	5.0
Kamloops, B. C.	1,262	28.83	30.17	+.21	27.6	−1.3	32.9	22.4	45	5	0.34	−0.44	2.7
Barkerville, B. C.	4,180	25.59	30.01	+.13	20.9	0.0	28.1	13.7	39	−20	1.40	−1.77	14.0
Estevan Point, B. C.	20				41.4		47.0	35.8	51	27	13.22		0.0
Prince Rupert, B. C.	170				39.5		43.8	35.3	51	25	4.98		0.0

Chart I. Departure (°F.) of the Mean Temperature from the Normal, January, 1929

Chart I. Departure (°F.) of the Mean Temperature from the Normal, January, 1929

Shaded portions show excess (+).
Unshaded portions show deficiency (—).
Lines show amount of excess or deficiency.
Statute Miles
Kilometers

Chart II. Tracks of Centers of Anticyclones, January, 1929. (Inset) Departure of Monthly Mean Pressure from Normal

(Plotted by Arthur J. Haidle)

Chart III. Tracks of Centers of Cyclones, January, 1929. (Inset) Change in Mean Pressure from Preceding Month

(Plotted by Arthur J. Haidle)

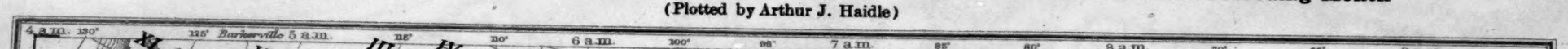

Chart III. Tracks of Centers of Cyclones, January, 1929. (Inset) **Change in Mean Pressure from Preceding Month**

(Plotted by Arthur J. Haidle)

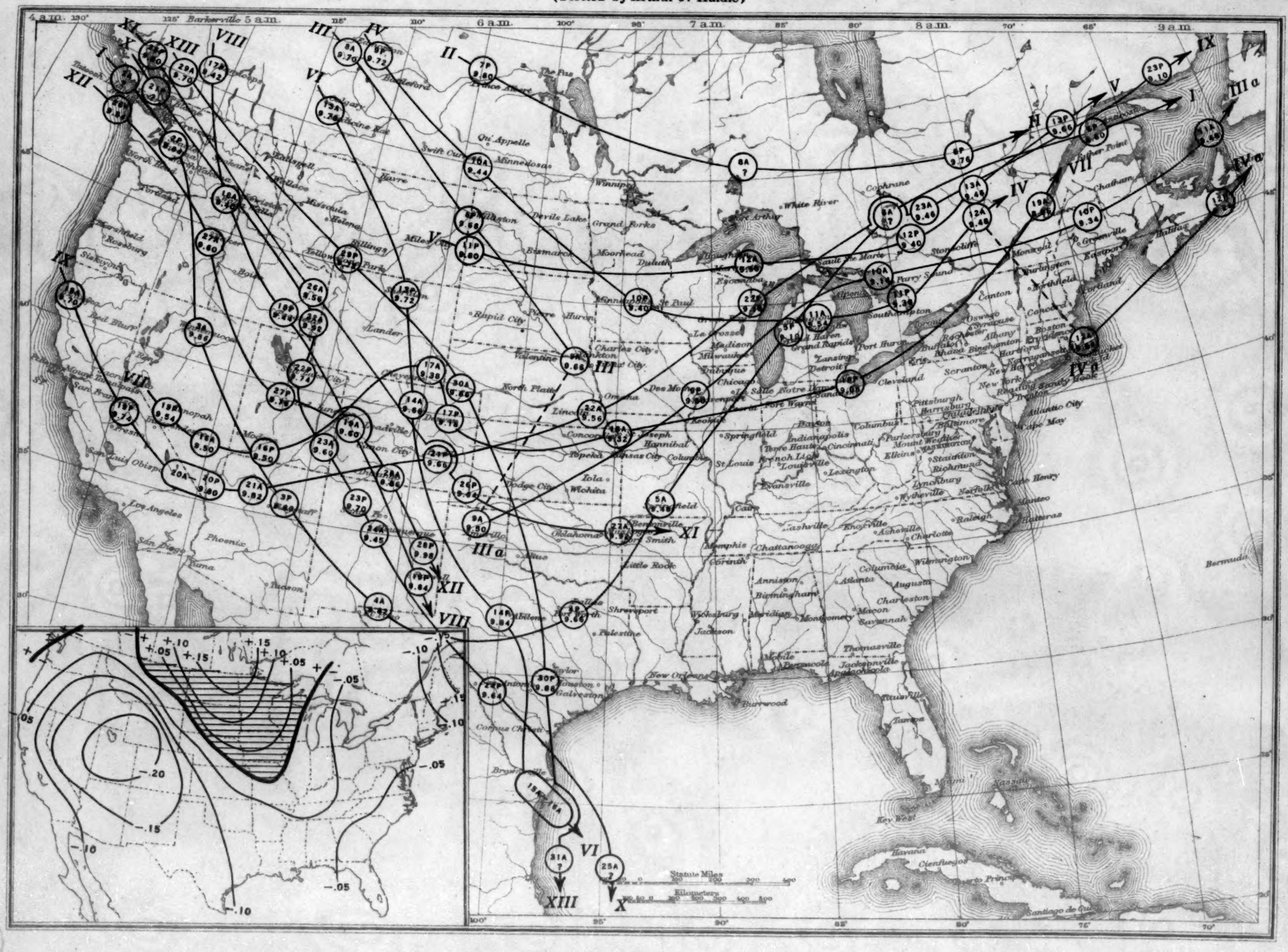

Chart IV. Percentage of Clear Sky between Sunrise and Sunset, January, 1929

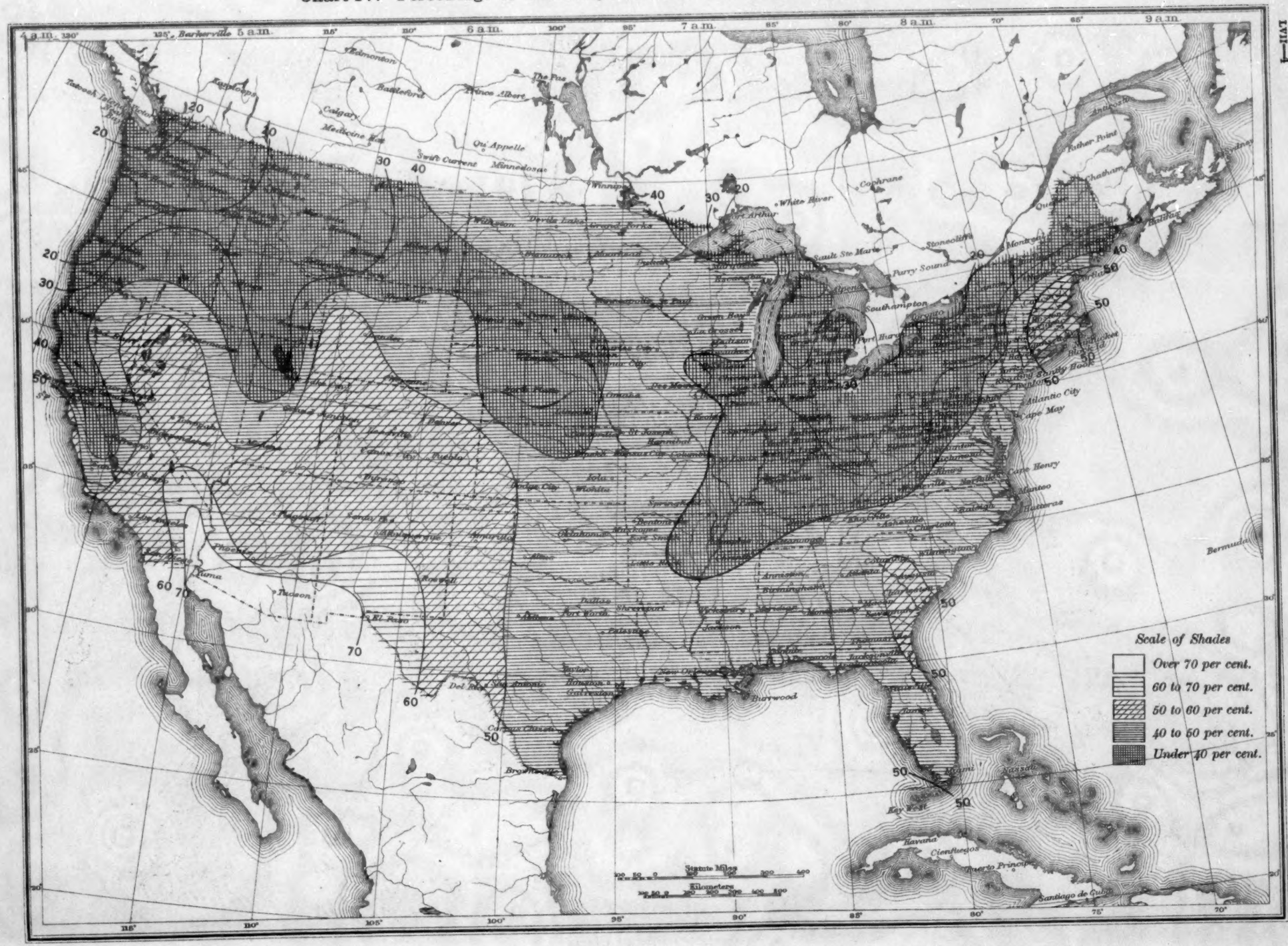

Chart V. Total Precipitation, Inches, January, 1929. (Inset) Departure of Precipitation from Normal

Chart V. Total Precipitation, Inches, January, 1929. (Inset) Departure of Precipitation from Normal

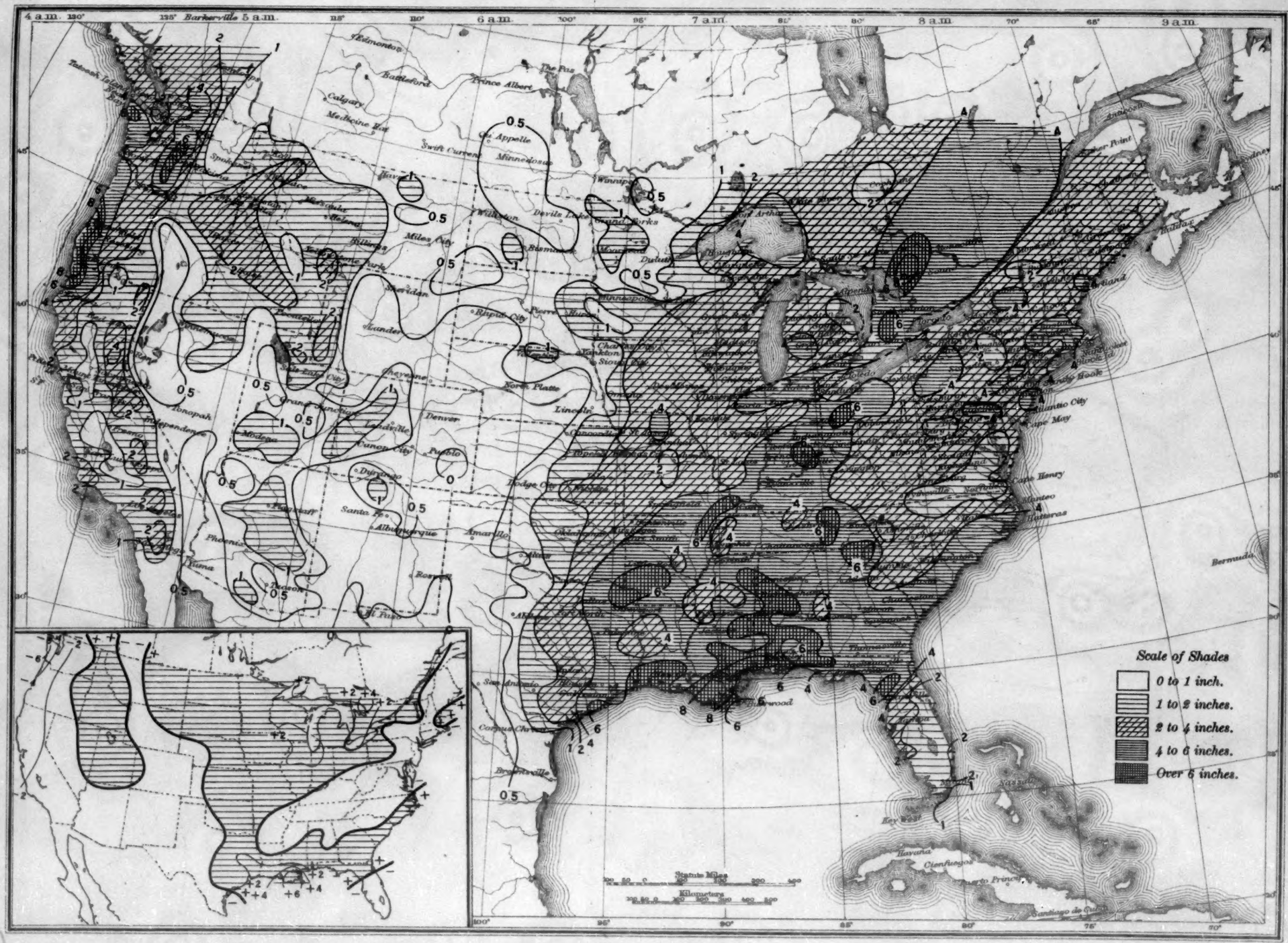

Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, January, 1929

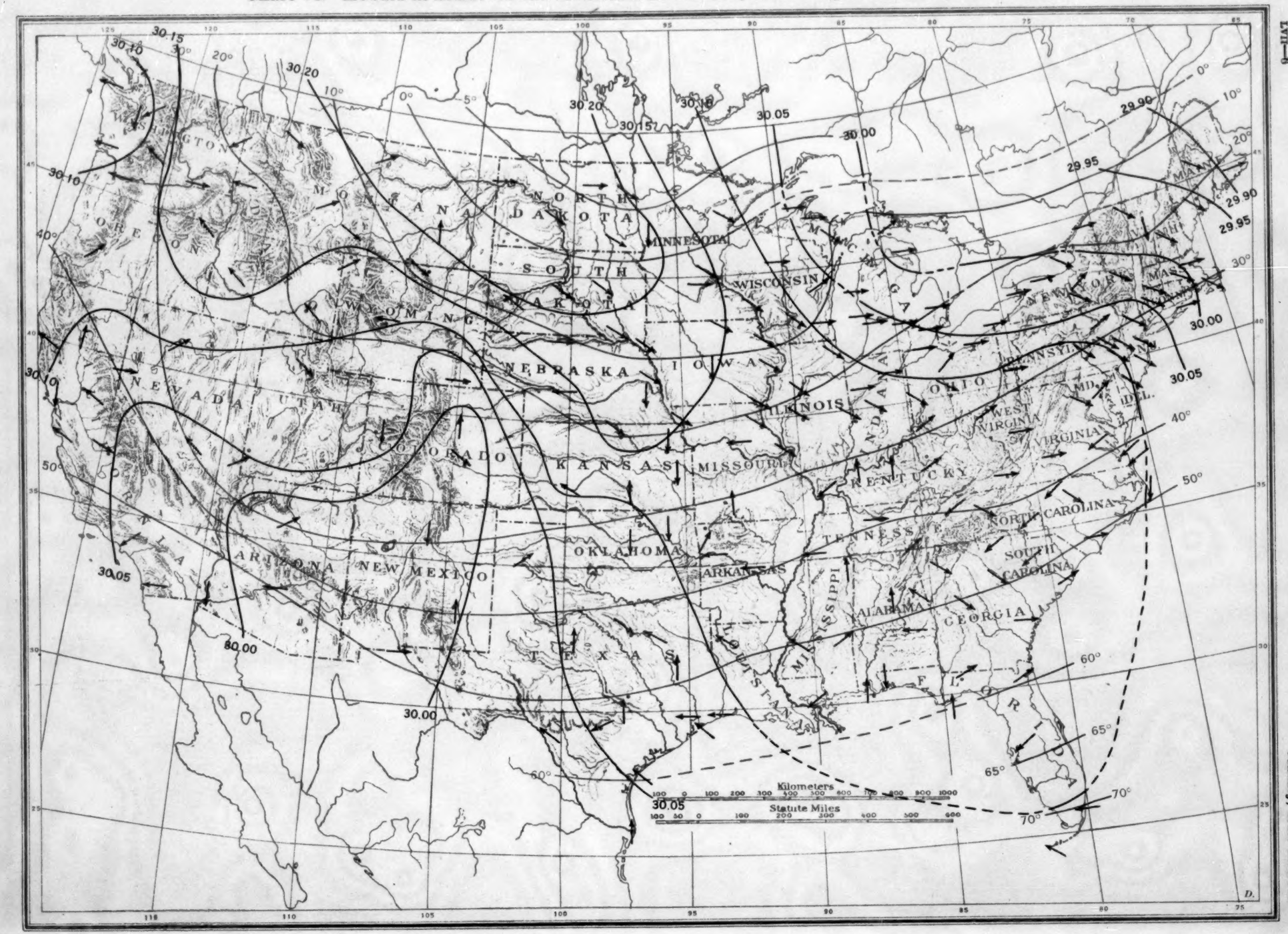

Chart VII. Total Snowfall, Inches, January, 1929. (Inset) Depth of Snow on Ground at end of Month

Chart VII. Total Snowfall, Inches, January, 1929. (Inset) Depth of Snow on Ground at end of Month

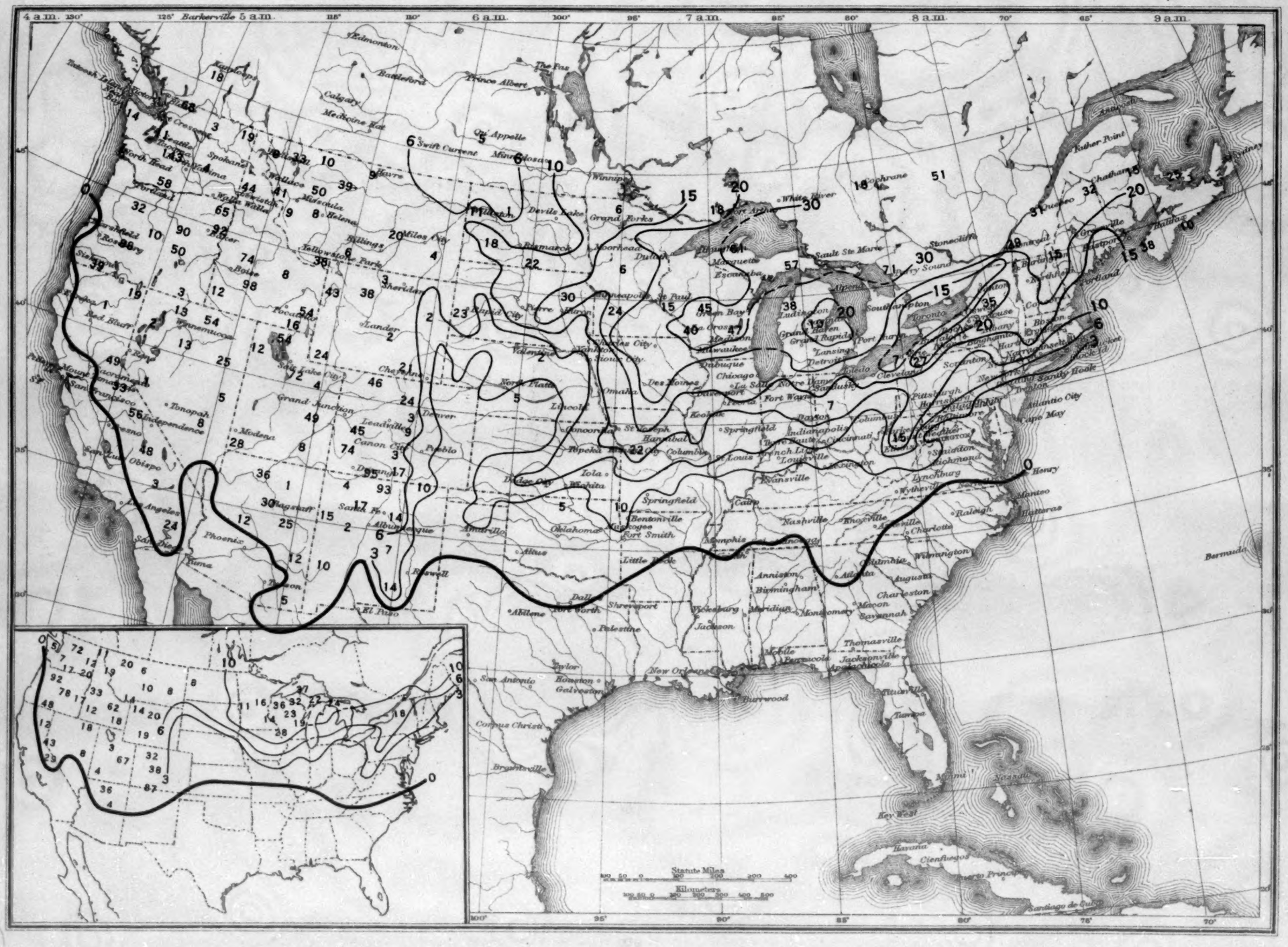

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Chart VIII. Weather Map of North Atlantic Ocean, January 20, 1929
(Plotted by F. A. Young)

Chart VIII. Weather Map of North Atlantic Ocean, January 20, 1929

(Plotted by F. A. Young)

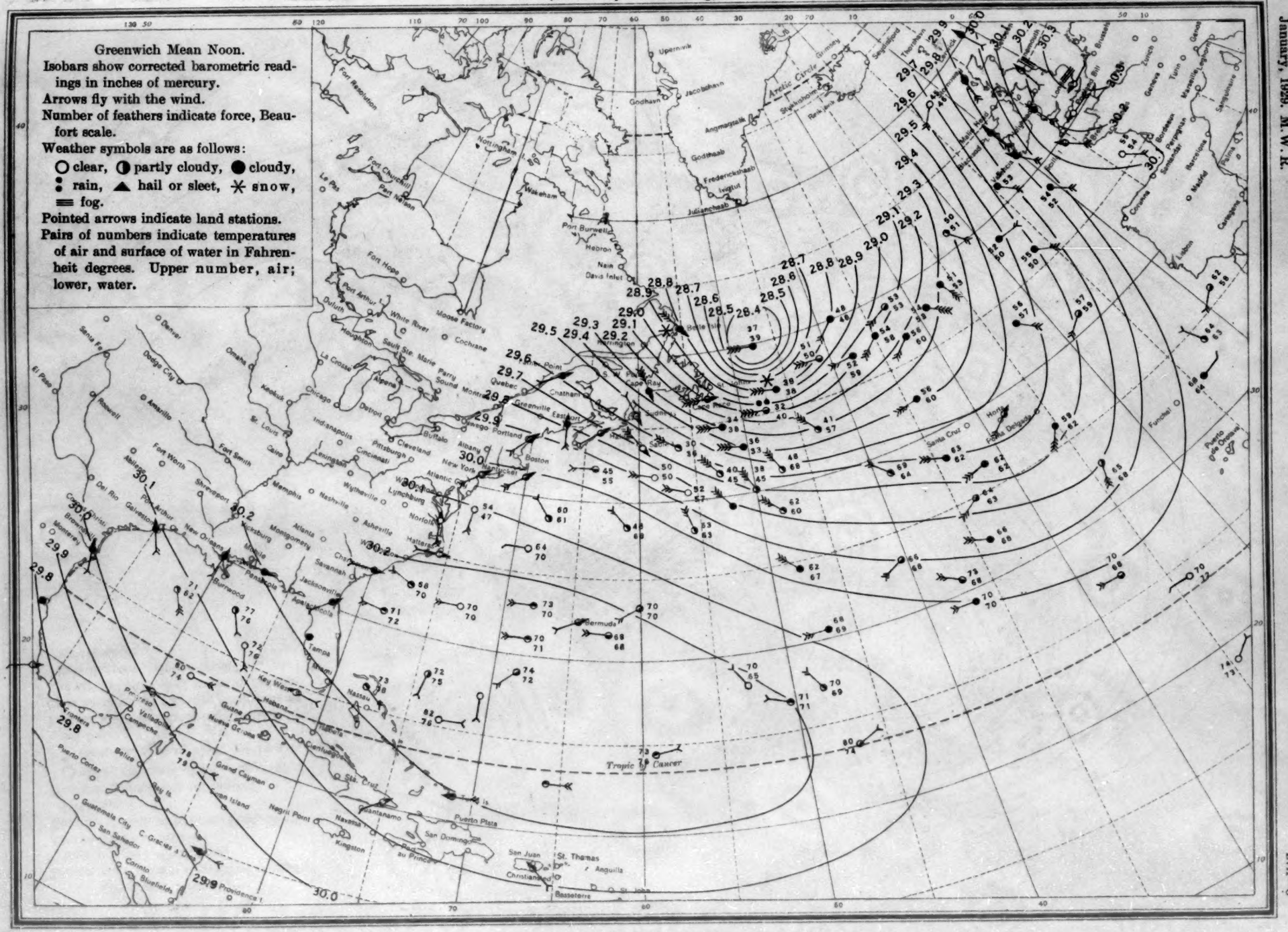

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Chart IX. Weather Map of North Atlantic Ocean, January 21, 1929

(Plotted by F. A. Young)

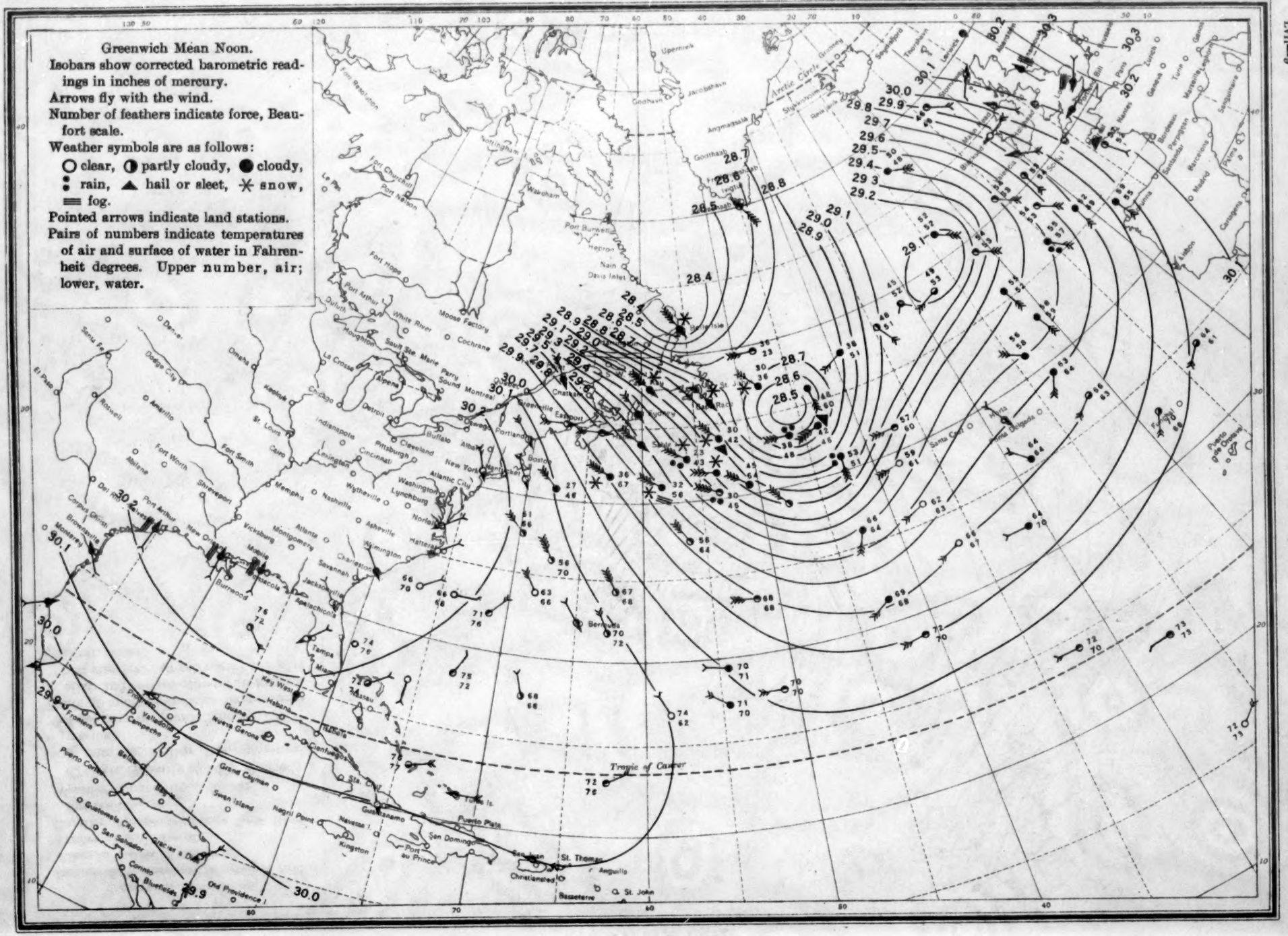

Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows:
clear, partly cloudy, cloudy, rain, hail or sleet, snow, fog.
Pointed arrows indicate land stations.
Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.
Arctic Circle
Tropic of Cancer

Chart X. Weather Map of North Atlantic Ocean, January 22, 1929

(Plotted by F. A. Young)

Chart X. Weather Map of North Atlantic Ocean, January 22, 1929

(Plotted by F. A. Young)

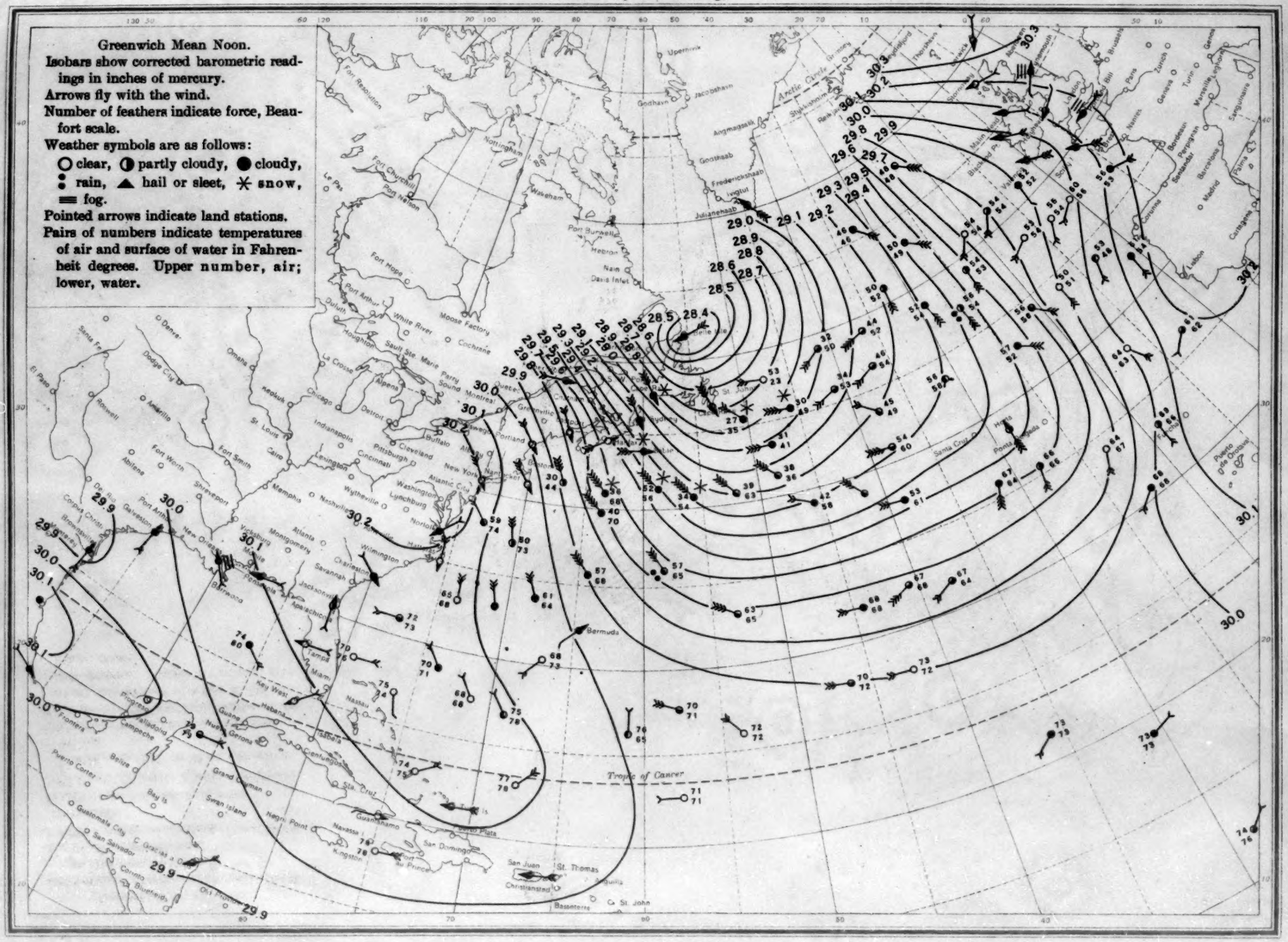


Chart XI. Weather Map of North Atlantic Ocean, January 23, 1929

(Plotted by F. A. Young)

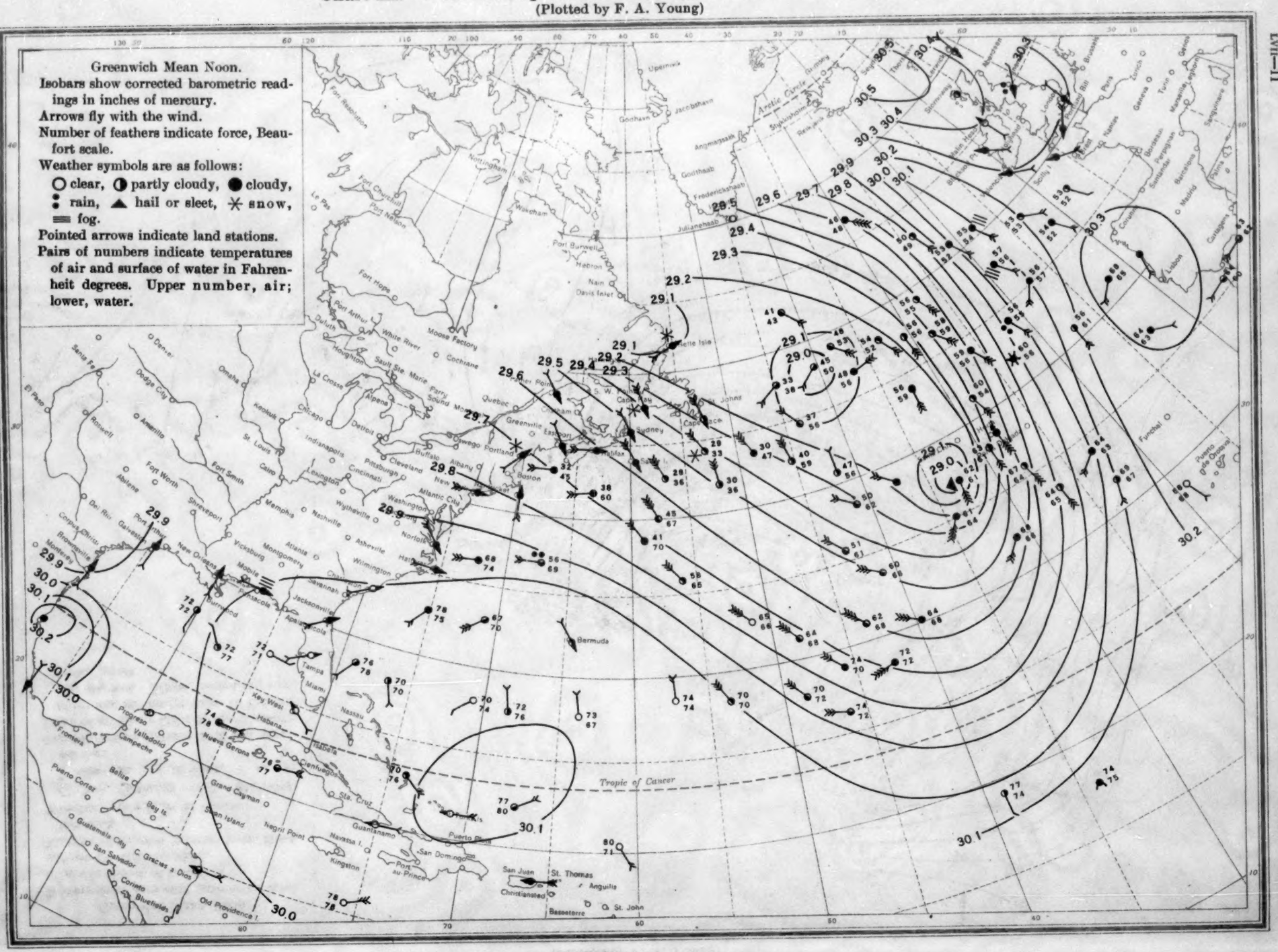


Chart XII. Weather Map of North Atlantic Ocean, January 24, 1929

(Plotted by F. A. Young)

Chart XII. Weather Map of North Atlantic Ocean, January 24, 1929

(Plotted by F. A. Young)

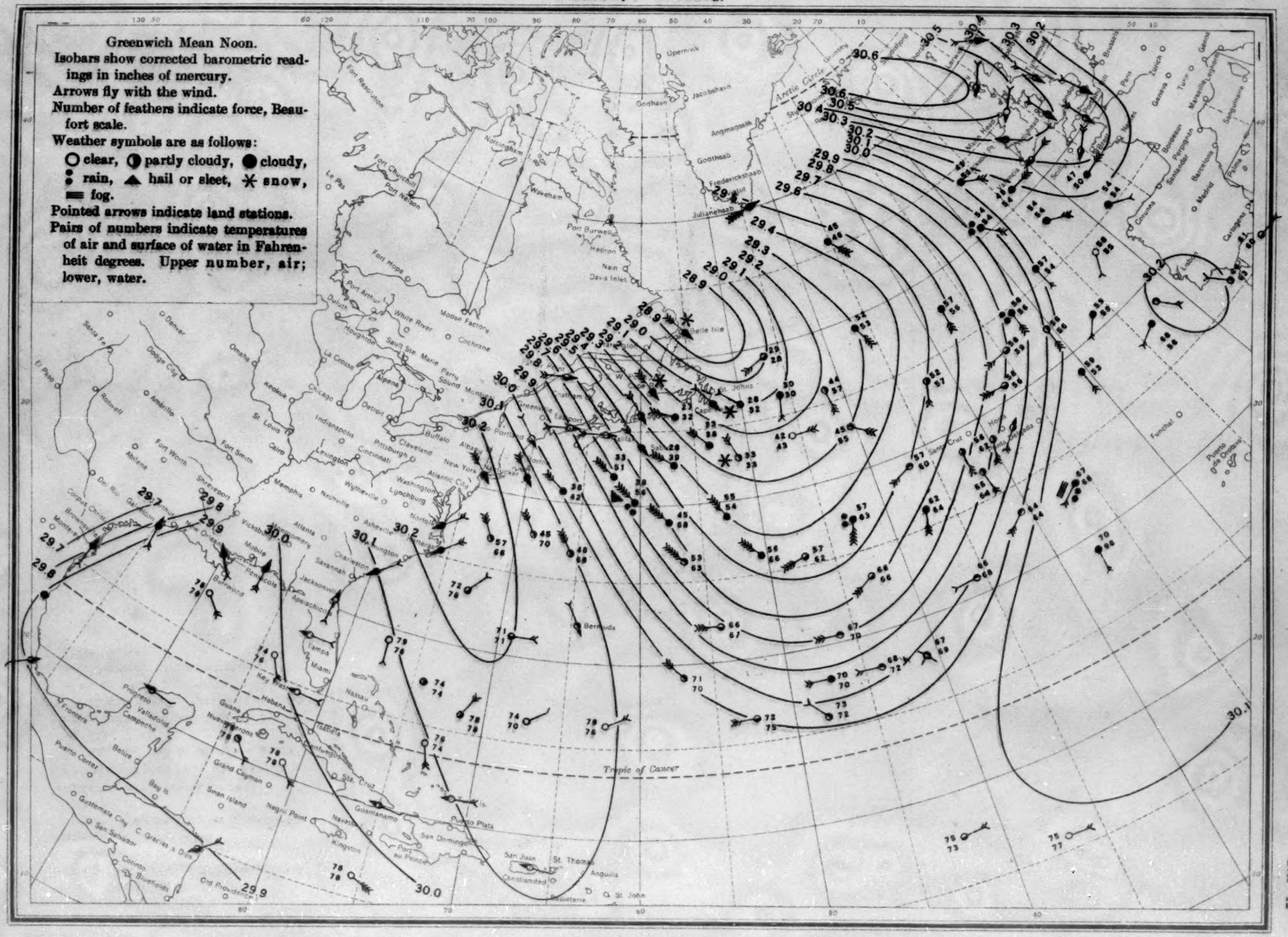
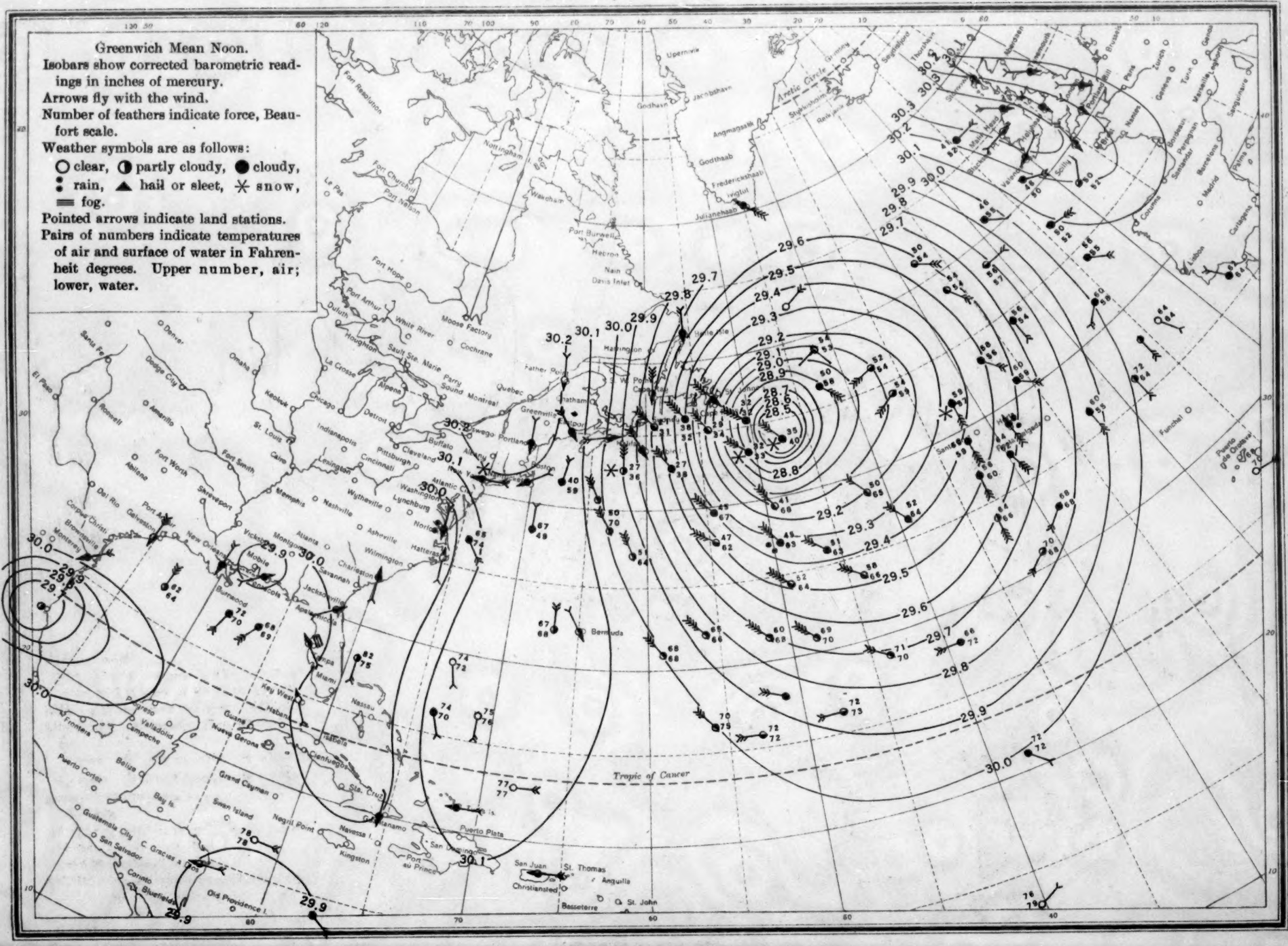


Chart XIII. Weather Map of North Atlantic Ocean, January 25, 1929

(Plotted by F. A. Young)


Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows:
clear, partly cloudy, cloudy,
rain, hail or sleet, snow,
fog.
Pointed arrows indicate land stations.
Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.
Tropic of Cancer
Arctic Circle